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BOSTON SOCIETY
OF
CIVIL ENGINEERS

FEBRUARY, 1928

Featuring

- General Principles of Welding
- Arc Welded Steel Construction
- Welding Trusses for Industrial Buildings
- Projection and Multiple Welds
- Reclaiming Waterwheel Casing
- Atomic Hydrogen Welding

Vol. XV

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JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

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GENERAL PRINCIPLES OF THE VARIOUS WELDING PROCESSES

By F. M. Farmer*

(Presented before the Affiliated Technical Societies of Boston, December 14, 1927)

The official definition of a weld, according to the standards of the American Institute of Electrical Engineers and the American Welding Society, is as follows:

> A solid union of metallic parts formed by either heating to a plastic or fluid state the surface of the parts to be joined and allowing the metals to flow together with or without additional molten metal and without any pressure being supplied; or by uniting or consolidating by hammering or compressing with or without previous softening by heat.

Welding without the use of heat is very little used in industry, and therefore this paper will be confined to the various welding processes which employ heat.

The various welding processes which are utilized in industry may be grouped into three general classes, — forge welding, fusion welding and pressure welding. Forge welding is, of course, the oldest of the welding processes. It is familiar to all of you and will not be discussed here.

---

* Chief Engineer, Electrical Testing Laboratories, New York; President, American Welding Society, New York.

Fusion Welding

Fusion welding includes those types where the weld is effected by fusing together the ends of the pieces to be joined by the application of heat and with or without the addition of extra metal but without the application of pressure. This general class of welding may be again subdivided into three general forms, — gas welding, electric arc welding and thermit welding.

Gas Welding. — In this form of welding heat is applied to the two surfaces to be joined by means of a flame resulting from the burning of a mixture of acetylene and oxygen. The combustion of these two gases makes one of the hottest flames known. The edges of the pieces to be joined, after previous suitable preparation, are held in position with the proper small clearance between them, heated to the fusion point by the application of this flame, and then metal is added by means of a welding wire much in the same general fashion as solder is added in an ordinary soldering operation.

The two gases are taken from tanks at high pressure, reduced through pressure-regulating valves, and mixed in the "torch" at the end of which the flame is produced.

The important features of a gas-welding operation are the proper mixture of the two gases so as to obtain complete combustion but without any excess of oxygen, the right size of flame for the size of work, the proper kind and size of welding wire, and, as in all welding operations, the proper technique on the part of the welding operator.

This process is particularly applicable to the welding of thin material because of the ready control of the intensity of the flame, and of the distance of the hot part of the flame from the work.

Electric Arc Welding. — The heat for welding by this means is obtained from the electric arc, — the hottest source of heat that we have. The arc is established between the edges of the pieces to be joined which serve as one electrode and a suitable rod which forms the other electrode. The two general subdivisions of this class of welding are indicated by the kind of electrode used, — carbon (or graphite) electrode or metal electrode.

In carbon arc welding, direct current is usually employed with the work as the positive side of the circuit because the positive crater of an arc is hotter than the negative crater. With the edges of the pieces to be joined heated to the fusion temperature by drawing an arc between them and a carbon or graphite rod, the necessary additional metal is supplied to the fused mass from a wire as in gas welding.

In metal arc welding, the welding wire itself is used as the electrode. Metal arc welding may be done with either direct current or alternating current, although direct current is the more generally used with currents ranging from 75 to 250 or 300 amperes at 15 to 25 or 30 volts, depending upon the size of the work, the size of the electrodes, quality desired, etc.

A most important feature of the arc-welding process is a short arc. Oxygen and nitrogen are obviously very readily absorbed from the air by the extremely hot metal thus forming ferrous oxides and ferrous nitrides which are extremely objectionable in the weld. The shorter the arc the less opportunity is there for absorption of this character. A steady arc of constant length is essential, hence automatic control of the voltage or current or both is provided in the special generators used in this work. Additional important features are proper current for the job, proper composition of the welding wire, and proper technique on the part of the operator, particularly with reference to obtaining the proper penetration.

Reference has been made to the deleterious effect of the absorption of oxygen and nitrogen. One scheme early developed to inhibit this action is to supply a protecting gas around the arc or a protecting slag on the molten metal by means of the addition to the welding wire of a suitable material as a core or as a coating on the outside. A more recent development is a scheme in which the arc in the regular metal-arc process is surrounded by a reducing gas, such as hydrogen, supplied through a concentric tube surrounding the electrodes.

Another recent development in the effort to overcome this oxidation problem in welding is the atomic hydrogen welding process. A stream of hydrogen is blown through an arc between two tungsten electrodes forming an open "V." The hydrogen molecules are broken up into atoms which immediately recombine into molecules a short distance beyond the arc, with the liberation of large quantities of heat at a very high rate, thus producing an intense flame completely free from oxygen and nitrogen. The process is used in much the same manner as is the gas-welding torch, wire being fed to the weld as in that process.

The surfaces to be joined must, of course, be thoroughly fused all over before they can be fused together. This requires a space between the edges so that the arc (or gas flame) will have access to the entire surface of the edges. Furthermore, when the pieces are over about one-quarter inch thick, it is necessary to bevel the edges so that the bottom parts of the surfaces will be accessible to the heat. This space is then all refilled with the molten metal supplied from the welding wire. Fig. 1 shows two types of joints in one-half inch steel plates known as "single V" and "double V," respectively. Proper penetration referred to in a previous paragraph means complete fusion over the entire surface between the parent or base metal, A, and the added or weld metal, B.

Arc welding by automatic machines has been developed to a high state for production operations. Not only is the current controlled as in hand welding, but the arc is held constant, the arc is automatically moved along the work at the proper rate, and the welding wire is automatically fed to the weld. Very high rates of welding with uniform quality are being obtained in a great variety of manufacturing applications.

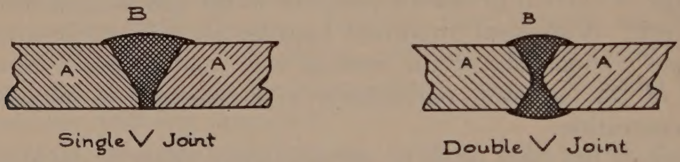

FIG. 1. — SINGLE V AND DOUBLE V JOINTS

Thermit Welding. — The principle of this process is the formation of a casting between the surfaces to be joined, the metal being poured in place with sufficient super-heat to fuse adjacent metal with it. Finely divided aluminum, which burns very readily with the production of a high temperature, is mixed with finely divided iron oxide in a suitable crucible. The mixture is ignited, and upon the completion of the reaction the molten metal at a very high temperature is poured into a suitable mold surrounding the joint to be made.

The process is in extensive use, particularly for large work, not only for joints between large pieces, but in effecting repairs on large parts. The various details for the various types and sizes of work have been carefully worked out in detailed instructions by the owners and controllers of the process, — the Metal and Thermit Corporation. Thus very little is left to the skill of the welder but to follow instructions.

PRESSURE WELDING

We will now turn to pressure welding, that type of welding where both heating and pressure welding are employed, as distinguished from fusion welding, where no pressure is employed. This general type may be subdivided into thermit pipe welding, resistance welding and percussive welding.

Thermit Pipe Welding. — The thermit process just described is also used in this class of welding, the parts to be joined being forced together under pressure at the proper stage in the process. In this application of the thermit process, no metal is added to the weld, — the super-heated metal being simply poured over the joint which is surrounded by a suitable mold. This heats the abutting ends of the pipe to the fusion point and then they are pressed together.

Resistance Welding. — Resistance welding is a very old electric welding process invented over forty years ago by Professor Thompson, one of our outstanding figures in electric science, and is now very extensively used in industry. It depends upon the principle that electric energy is converted into heat when it is forced through electrical resistance, that is, current flowing through resistance produces heat proportional to the product of the resistance and the square of the current. If, therefore, there is a spot of relatively high resistance in an electric circuit heat is developed at that spot. If two metal rods are butted together, end to end, the resistance across the joint will be much higher than in an equal length of any part of the rods. With sufficient current fusion of the end surfaces takes place. Then, if the current is interrupted and the rods pushed together, a weld will be made.

It is evident that the practical application of this process is a strictly mechanical operation compared with hand welding with gas and the electric arc. The most extensive development has been in the methods using large alternating currents at low voltages, because alternating current can very readily be transformed from normal commercial voltages to the low voltage needed.

Resistance welding can be subdivided into three general classes, — namely, butt welding, spot welding and seam welding.

(*a*) The simple process just described is known as butt welding. This type of welding has been applied to extremely large work, — as high as 35 to 40 square inches of abutting surfaces employing currents over 100,000 amperes with a transformer capacity of the order of 1,000 kva. and utilizing pressures of the order of 100 tons.

Butt welding is now usually modified to employ what is called the "flash" principle; that is, a very small gap is left between the abutting pieces so that with a somewhat higher voltage minute arcs are produced across the gap. Thus the high temperature associated with arcs is produced at the surfaces which are instantly converted to the molten condition. They are then forced together under high pressure. This method is quicker and causes less upsetting of the metal with the accompanying burr which has to be subsequently removed.

(*b*) Spot welding is an application of the butt-welding idea to "spots" between flat pieces, as shown diagrammatically in Fig. 2. The current is restricted to a spot by the copper studs or electrodes to which pressure is applied when the fusion point is reached.

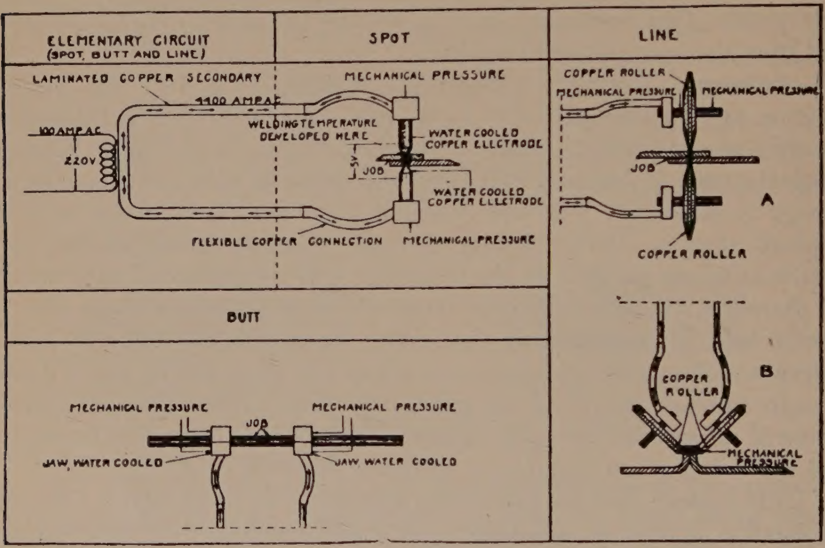

FIG. 2. — SEAM WELDING

(*c*) Seam welding is also an application of the butt-welding idea wherein what is in effect a continuous series of spot welds is made forming a continuous joint along a line between two flat pieces. The studs are replaced by copper roller electrodes between which the work is moved. The scheme is shown diagrammatically in Fig. 2 where two applications are indicated, — surfaces horizontal and surfaces vertical.

Percussive Welding. — This is an interesting form of resistance welding wherein the electrostatic energy in a charged electrical condenser, or the electromagnetic energy in a magnetized magnetic circuit, is suddenly discharged across the joint to be welded. The surfaces are instantly heated to the fusion point and then the application of pressure completes the weld. This method is particularly suitable for small work. The rapidity of the operation and its applicability to any metal or combination of metals makes it effective in the welding of very small pieces such as jewelry.

SUMMARY

Fig. 3 is a diagram summarizing the relations between the various processes. It will be noted that there are a number of special forms of butt, spot and seam welding, respectively, which time has not permitted discussing.

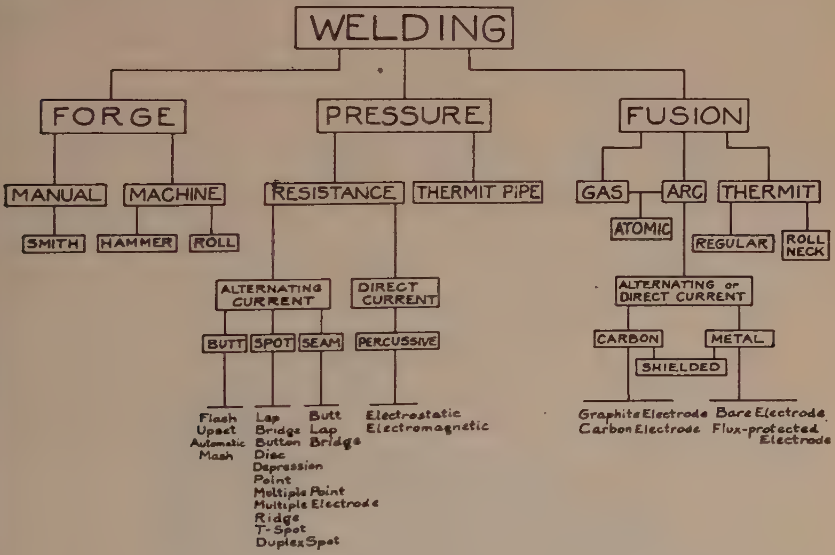

FIG. 3. — RELATIONS BETWEEN VARIOUS PROCESSES OF WELDING

GENERAL COMMENTS

The fusion-welding processes, that is, gas welding and electric arc welding, appear to be very simple operations. As a consequence in the early days of the art too much was left to the welder. Welding was treated as a trade, like blacksmithing and plumbing. The importance of the many elements so essential to consistently good welding was not appreciated, and the result was that much poor work was done. Quoting from a paper by Prof. C. A. Adams, the first President of the American Welding Society, and the father of the movement to put welding among the most important of the mechanical arts:

> The factors entering into the success of the applications of welding to any particular field are numerous and should be controlled by a man who is familiar not only with the practical or technical part of the job, but also with the underlying scientific principles; who can co-ordinate his experience; lay out appropriate tests to determine the feasibility of some new application, extension or improvement of the art; can

design the structure to be welded in such a way as to effect the greatest saving without sacrifice of the effectiveness of the structure for the purpose in hand; can select the most appropriate method of welding and the best apparatus; can design special apparatus when the need arises; and can organize the work and his operators for maximum efficiency. In short, he should be an engineer. Many of the early failures which contributed so much to the distrust of welding on the part of the conservative minded, could have been avoided if this need had been appreciated. The welding factors referred to above may be roughly grouped under the following headings: design, material, apparatus, welding operators, technique of welding and inspection and testing.

The American Welding Society

The American Welding Society is a technical society organized for the purpose of promoting the art and science of welding.

This purpose is carried out by all of the usual means, — meetings of both the national body and its various sections with technical papers and discussions, the publication of a monthly journal, an annual exposition showing the progress in the art, establishment of standards of various kinds, and the fostering and sponsoring of co-operative research in the welding field. Two important researches to cost $25,000 or $30,000 are now under way. One is for the purpose of developing the most efficient and effective form of joints in building structures when specially designed for welding, and to obtain data upon which to base strength constants in design calculations. The other research is to obtain reliable data on welded pressure tanks of various sizes and thicknesses by means of tests to destruction, which will aid the A. S. M. E. Boiler Code Committee and other bodies having to do with regulations governing the use of pressure vessels. In fact, the Society considers that any proper activity which will advance the welding art, whether it be scientific fundamental research, technical research, professional engineering matters, extending the field of application of welding, or a commercial problem, is within its scope.

The Society is composed of individuals and companies interested in welding in any way, — as manufacturers or purveyors of apparatus or supplies, or as users of the art.

EXAMPLES OF ARC WELDED STEEL CONSTRUCTION

By Gilbert D. Fish*

(Presented before the Affiliated Technical Societies of Boston, December 14, 1927)

The Westinghouse tests at Carnegie Institute last year, where 42 arc welded structural steel joints were loaded to destruction, were part of the preliminary work in an organized movement to replace riveting by more economical means for connecting members of steel structures.

These tests proved that arc welded joints could be made stronger in every way than the members joined, and that arc welded plate girders assembled from plate material only could be made to resist greater bending moments than riveted plate and angle girders of the same depth and weight. One case (Fig. 1) will be enough to illustrate the 100 per cent cantilever joint which can be produced by welding but not by riveting;

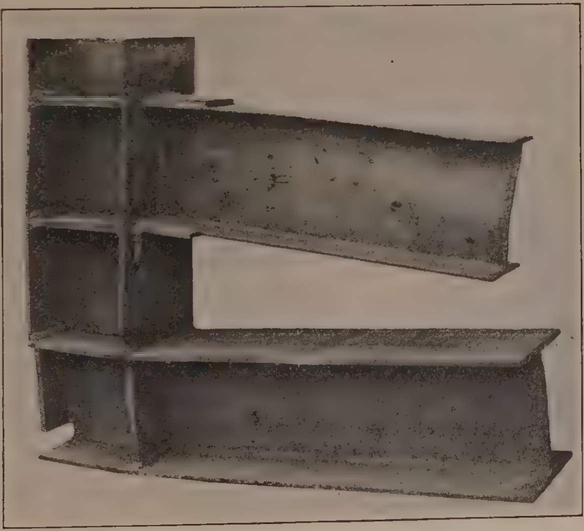

Fig. 1. — Cantilever Joint produced by Welding — After Test

this 12-inch I-beam was bent to failure at 200,000 foot-pounds moment without distress in the welded joint. The chief applications of this type of joint are in continuous beam construction and in wind bracing.

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* Consulting Engineer, Westinghouse Electric and Manufacturing Company, New York.

Buildings erected since these tests were made have contained numerous examples of the kinds of connection illustrated by the tests. Continuous beam construction by means of welded cantilever joints reduced the amount of steel required for beams and girders in the Sharon Building, reduced deflection and vibration of the floor system, and increased lateral stiffness of the whole frame. Plate girders assembled from plate material by welding are in use, supporting heavily loaded columns over 45-foot spans in the Sharon Building and carrying locomotives over the 55-foot railroad span of the Westinghouse Interworks Railway near East Pittsburgh. Roof trusses, assembled by welding from plain material without holes and with few or no gussets, are supporting roofs on buildings too numerous to mention. A new railroad bridge, through truss skew type with 135-foot span, is under construction at Chicopee Falls, with continuous floor stringers, floor beams of heavy rolled sections with welded cover plates, truss tension members with welded connections developing 100 per cent of the tensile strength of gross sections, and connection materials amounting to only about 3 per cent of total steel.

Cost Savings in Welded Construction

There are two classes of cost savings in welded construction, — namely, reduction of steel tonnage both in members and in connections, and savings in the cost per ton. Too much emphasis on either class sacrifices savings in the other class. In building construction there are opportunities to save material by continuous beam design, and to save detailing and fabrication costs by arranging so that the columns are the only, or almost the only, members requiring fabrication. In bridge trusses and towers large percentages of weight are saved by eliminating or greatly reducing gusset plates and other connections and by avoiding loss of effective cross section of tension members at rivet holes; detailing and fabrication are simplified by limiting holes to those needed for erection bolts. No general statement can yet be made as to whether the welding work itself costs less or more than the riveting in equivalent structures; it may cost either less or more, depending on the division of work between shop and field, on the kind of structure, and on the way in which it is designed for welding. The amount of welding may advantageously be increased if so doing decreases the quantity of steel or simplifies other operations. What is quite evident is that a net reduction in cost of a complete structure depends on saving steel and reducing fabrication. In welded construction there is no item of preparation for the welding operation corresponding to the laying out and punching of holes necessary in preparation for riveting.

The success already obtained by arc welded construction in cost competition with older methods is a sure indication of inherent economics, because a new and unfamiliar method is at serious disadvantage at every stage. As design economy becomes better understood, as shop arrangement and equipment become adapted to welded fabrication, as labor becomes more efficient in handling the methods, and as high speed automatic welding reduces welding cost, the relation of cost between welded structures and riveted ones will vary rapidly in favor of welding. Far-sighted fabricators are already laying their plans to move with the times, and even those who are holding back know that if welding reduces costs only 5 per cent they cannot long remain in business with methods unchanged.

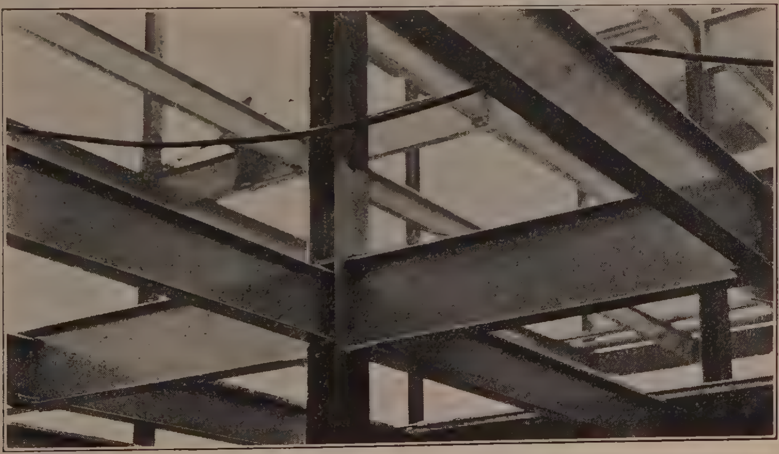


FIG. 2.—SHARON BUILDING—CANTILEVER TYPE WELDED JOINTS

THE SHARON BUILDING

The Sharon Building is by far the largest and heaviest welded building thus far constructed. It was planned by the Westinghouse Electric and Manufacturing Company as an example of arc welding applied to heavy construction, and was built by the American Bridge Company a year ago. The dimensions are 220 feet by 70 feet by 80 feet height, and the steel tonnage is 790. Complete continuity of floor beams and girders was obtained by welded joints of the cantilever type. The detail of these joints, which will never be quite duplicated because more economical ones can be made to serve the same purposes, required all members to go through the shops for cutting to nearly exact length and for punching erection holes.

SAVING OF 100 TONS

Continuity made possible the substitution of 15-inch I's for 18-inch I's, and of 20-inch I's for 24-inch I's, and caused most of the saving of about 100 tons as compared with the riveted design. Two wrong impressions are in circulation due to incorrect interpretation of some published statements about this job. One is that welded construction requires all members to be milled to exact length, — a completely erroneous idea as shown by the recently erected Derry Building, for which 60 per cent of the steel was not fabricated at all. The other is that continuity of beams is uneconomical because it costs more in labor than it saves in material. It is true that the final cost analysis of the Sharon Building did not make a good showing for continuity of beams as carried out in that job, but if I were laying out that job again the continuity feature would be retained and would be made to pay by using joints with less welding and without the requirement for milling the beams.

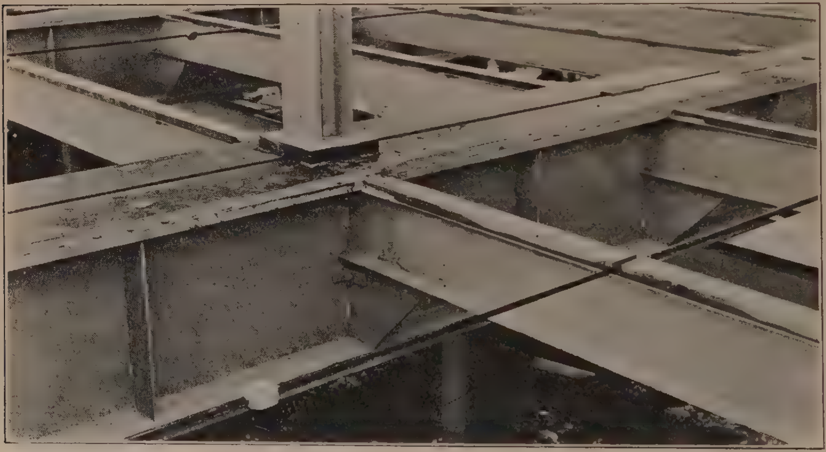


FIG. 3. — SHARON BUILDING — PLATE GIRDERS

The plate girders in the second floor of the Sharon Building were 45 feet in span and weighed eighteen tons per pair. They were designed to carry floor load plus 325,000 pounds of column load at the middle of each pair. Riveted girders of the same outside dimensions and strength would weigh about 10 per cent more because the flange angles would reduce the effective depth and because holes in tension flanges would require compensating material.

CONTINUITY TESTED WITH HYDRAULIC JACKS

A pair of hydraulic jacks with eye-bars used to anchor them to columns one story below were used on a pair of typical 20-inch beams in the Sharon Building to test continuity at the two interior column joints of the three beams affected. The jack loads, which were simultaneously applied, produced a continuous elastic curve conforming quite accurately to the calculations and proving that full continuity existed. The calculated maximum bending stress due to the pair of equal loads was the maximum positive bending stress in the outer loaded beam, and was about equal to the elastic limit.

DERRY BUILDING

The new arc welded building of the Westinghouse High Voltage Insulator Company at Derry, Pennsylvania, is a one story mill type building 460 feet long and covering two acres. The steel contractor was Jones & Laughlin Steel Corporation, with erection subcontracted by Minnotte Brothers Company. The steel tonnage was 337. The purlins were made continuous and designed accordingly, the saving in steel on this item clearly paying for the extra welding, with a good margin to spare. Otherwise there was a stark simplicity of design and detail. There were 135 18-inch I rafters on 30-foot span, and 6 24-inch I 115-pound rafters on 52-foot span. Each rafter was connected to the column at each end by a single side angle welded to the rafter before erection and to the column after erection, the only holes for erection bolts being two in column flange and two to match in outstanding leg of angle. The columns had to be milled for bearing, anyway, and the punching of the columns was therefore only a moderate extra cost. The angles were welded to the rafters on the ground before erection. This arrangement permitted shipment of rafters from mill to site as plain material, with ordinary mill tolerances in length.

The purlins also were plain mill material and were erected by lowering them into receptacles formed of short pieces of 5-inch channel tack welded to top flanges of the rafters before erection. Continuity was obtained by welding tension straps to top flanges of purlins and butt welding the bottom flanges. Most of the spandrel beams passed through the shop to be punched for holes for bolting wood facias. If the building had been of fireproof construction this punching would have been avoided and a larger proportion of the steel would have been shipped plain.

It is evident that the preparatory welding of plain material might have been done at a shop instead of on the ground. The use of cranes for sorting and shifting, the avoidance of weather interference, and the lower scale of wages on shop operations would all have reduced cost, but the extra transfer of material, the extra sorting, and the shop overhead expense might have offset those savings.

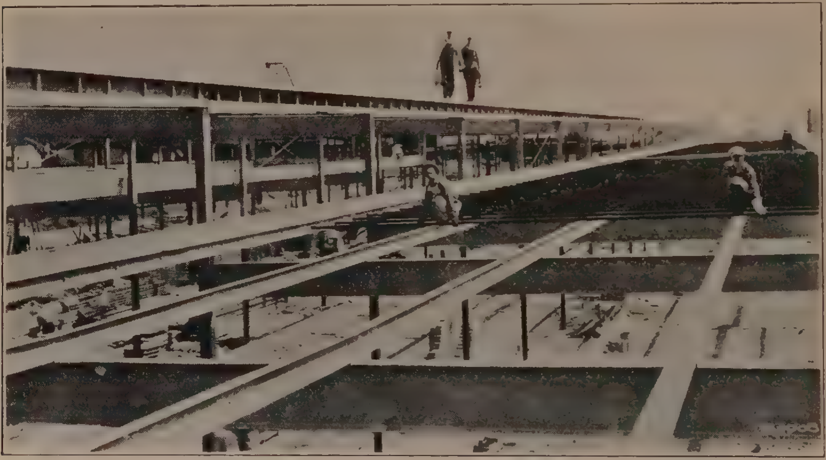


FIG. 4. — ARC WELDED BUILDING OF THE WESTINGHOUSE HIGH VOLTAGE INSULATOR COMPANY

It is estimated that the Derry steel work cost about 12 per cent less than it would have cost according to the alternative design for riveting. The cost analysis is given in the following table:

DERRY BUILDING FIGURES

ITEM	Estimate	Average per Ton
Steel on cars at building	$17,070	$50 66
Erecting and painting	6,232	18 49
Welding and special engineering	3,280	9 73
Complete structure	$26,582	$78 88

Approximately, these items may be considered further divided, as follows:

Plain material on cars at building, 200 tons at $42.20	$8,440
Fabricated material on cars at building, 137 tons at $63	8,630
Erecting and painting, 337 tons at $18.49	6,232
Ground welding, 858 feet at $1.45	1,240
Welding in place, 1,402 feet at $0.88	1,240
Welding sketches and special engineering	800
Contract price	$26,582

CHICOPEE FALLS BRIDGE

The Chicopee Falls bridge is a single track through span to carry a spur track of the Boston & Maine Railroad across the power canal of Chicopee Falls, Massachusetts. The spur is to serve the Westinghouse plant located there, and will be owned by the Westinghouse Company. Like other Westinghouse engineering operations this project is under Mr. W. S. Rugg, Vice-President. Operation across the bridge will be by the Boston & Maine, and for this reason the design has been subject to the approval of the railroad's Engineer of Structures, Mr. B. W. Guppy. The contract was awarded by Mr. A. B. Reynders, Works Manager of the Westinghouse Plants at Springfield and Chicopee, to the Palmer Steel Company, on a lump sum basis with foundations included. This fact makes it difficult to issue an accurate statement of the amount saved by the owners because of substituting welding for riveting, the bids taken for riveted construction not having included foundations. However, the cost of a separate foundation contract was nearly enough known to make it clear that welding was the means of bringing the total cost within the appropriation.

Tarbell & Leete, contractors, are associated with the Palmer Steel Company on this job as foundation builders and erectors. The ban against using falsework in the canal except at night and on holidays led to the decision to erect the bridge on one bank and move it bodily into place. It will not be necessary to complete the welding before the bridge is seated, but the erector will suit his convenience about this. Two welding operators are employed, Mr. William Norberg in charge.

The bridge has a 72° skew, and although the span of each truss is 134 feet 8 inches, the overall length of bridge is about 175 feet. The width center to center of trusses is 17 feet, and the height center to center of chords is 24 feet 8 inches. The original design was for a riveted bridge of the same dimensions, with Cooper's E 60 live loading and conventional impact and wind allowances, basic design stress 16,000 pounds per square inch. All truss members were built-up sections, and floor beams were plate and angle girders, but stringers were I-beams. Total steel in this design was 140 tons. Revision of the design for E 50 loading would have reduced this tonnage to 120.

The design for welding, on the final basis of E 50 loading, calls for 80 tons of steel, or one-third less than the equivalent for riveted construction. More than half of the saving is in reduction of connection material; only 7 of the joints in each truss, or about 1 in 4, have gusset plates, and these few gussets are only about one-fifth as large on an average as gussets adequate for riveted joints. Most of the remaining saving is about equally divided between reduction of tension members, due to eliminating the allowance for holes and reduction of stringers, due to continuity through the floor beams.

All members of the bridge are single shapes, except the cast-iron pedestals at the abutments and the floor beams, consisting of rolled beams with welded cover plates. All chord and diagonal members are Carnegie wide-flange beams of the 10-inch constant depth group. Other members are an assortment of standard I-beams, Carnegie wide-flange beams, angles and small H-beams. No channels are used. The convenience of the constant-depth beams for truss members is most apparent at the gussets, filler plates being far more objectionable in welded joints than in riveted ones.

A lower chord joint formed with gussets, and a chord splice with slot welds, one-half inch square in section, connect the members to the gussets by transferring shear from flange of member at bottom of slot to gusset plate at both edges of slot. Triangular fillet welds assist the slot welds by transmitting shear from edges of flanges of members to inner faces of gussets. Slot welds are very compact, 1½ inches of one slot being an approximate equivalent to one ⅞-inch rivet in single shear. The value of a ⅜-inch fillet weld is roughly half that of a ½ x ½ inch slot weld. The manifest impossibility of concentrating a like strength in rivets within the same space accounts for the comparatively small size of gussets. The tension splice is located beyond the gussets to avoid increasing gusset thickness beyond the one-half inch required for web member connections. Most of the splice stress is transmitted by butt welds having the same cross section as the smaller member, and figured at 13,000 pounds per square inch; the stress in the chord member being 16,000, the butt welding takes care of thirteen-sixteenths of the splice load, and the remaining three-sixteenths is accounted for by the two splice plates, which are also used for erection bolting. The flanges of the lighter chord member are beveled on the outside at 45°, and its web is beveled on the top side at 45°, to facilitate butt welding; the splice plates are to be removed temporarily to permit the flange welding.

The shear connection for the floor beam is a triangular butt weld, naving a minimum section 5/8 inch by 18 inches to resist a shear slightly under 100,000 pounds. The single side angle on far side of beam web s for erection only. The joint is protected against bending stress by a single angle knee brace at 45°. In view of the inflexible character of

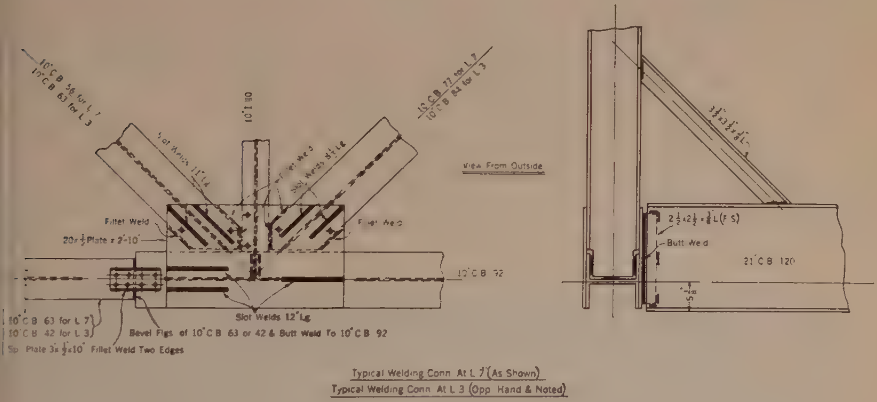
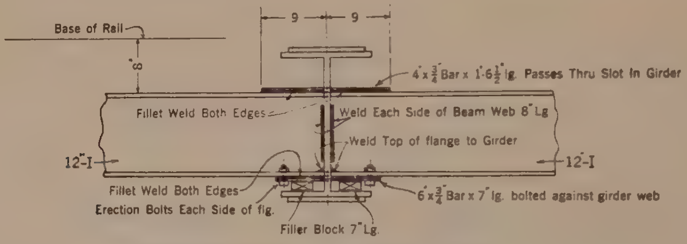


FIG. 5. — CHICOPEE FALLS BRIDGE — LOWER CHORD JOINT

he knee brace connections, which consist of direct welds between knee nd members, a calculation was made to determine approximately the naximum knee brace tension due to reaction of the stiff vertical truss nember against deflection inward to permit sag of the floor beam under ocomotive loading. This is mentioned as an example from among the itfalls against which an engineer must guard in turning from older nethods to the design of welded structures.

The chord tension is developed by butt welding of flanges only and y slot and fillet welds at the splice plates. The end post is drilled for he pin, which is shop welded in place. The pin pedestal is made of lates welded together in the shop. The cast-iron pedestal, although nore expensive than a steel billet, is used for its superior rust resistance, he abutment being nearly flush with high water in the canal.

In upper chord joints where gussets are used the chord members re milled and butted, the gussets being used only for web member stresses nd for securing the chord members in position. In typical stringer onnections the floor beam web is slotted to pass a tension bar connecting top flanges of opposite stringers. The compression bars under the bottom flanges are butted against the floor beam web. Fillet welds transmit the tension and compression forces of the negative bending couple from stringer flanges to bars. Fillet welding between ends of stringers and web of floor beam is used to carry most of the vertical reaction and to assist in resisting the negative bending; a minor fraction of the vertical reaction is considered to be transmitted to the bottom flange of the floor beam through the erection blocks. The purpose of continuity of stringers is twofold,— first, to prevent the stringers from sloping at their ends when live load is applied, this repeated motion being a serious source of fatigue in riveted stringer connections; second, to reduce bending moments and thereby permit use of lighter stringers.


9
9
Base of Rail
8"
4"x 3/4" Bar x 1'-6 1/2" lg. Passes Thru Slot In Girder
Fillet Weld Both Edges
Weld Each Side of Beam Web 8" Lg
Weld Top of flange to Girder
12"-I
12"-I
Fillet Weld Both Edges
Erection Bolts Each Side of flg.
6"x 3/4" Bar x 7" lg. bolted against girder web
Filler Block 7" Lg.

Stringer Beams Cold Sawed to allow abt. 1/8" clearance each end

FIG. 6. — CHICOPEE FALLS BRIDGE — STRINGER CONNECTION

Erection bolts are used for all stringers, floor beams, main truss members and bracing members too heavy for two men to handle without a derrick. Welding quantities are as shown in the following table:

WELDING, QUANTITIES, CHICOPEE FALLS BRIDGE

	Shop	Field	Shop and Field
38-inch triangular fillet .	308 linear feet	562 linear feet	870 linear feet
Butt and slot welds . .	88 cubic inches	450 cubic inches	538 cubic inches
ALL KINDS	348 cubic inches	921 cubic inches	1,269 cubic inches

Two welders are employed for all welding both shop and field, using Westinghouse motor-generator sets on wheel trucks, 200 ampere rating. There is estimated to be 50 man-days of welding altogether. Westinghouse uses and recommends direct current only for structural arc welding.

It is expected that this bridge and the welded bridges of the future vill prove somewhat more permanent than riveted ones, because the mmovability of the joints removes the chief cause of fatigue. Although veld metal is less ductile than rivet steel, a properly designed and exeuted welded joint should have greater endurance under stress reversals han a good riveted one, because in the case of the latter the connecion members and rivets are subject to slight motions back and forth, requently beyond the elastic limit. Another factor favoring long life or welded joints is their smoothness and absence of rivet heads, with coresponding ease of painting and lessened tendency to corrode.

PLATE GIRDER RAILROAD BRIDGE

The girders of the 55-foot through plate girder span recently put nto operation on the Westinghouse Interworks Railroad near East ittsburgh, Pennsylvania, were assembled by welding plate material nly; the floor stringers were made continuous in the same manner as n the Chicopee Falls bridge.

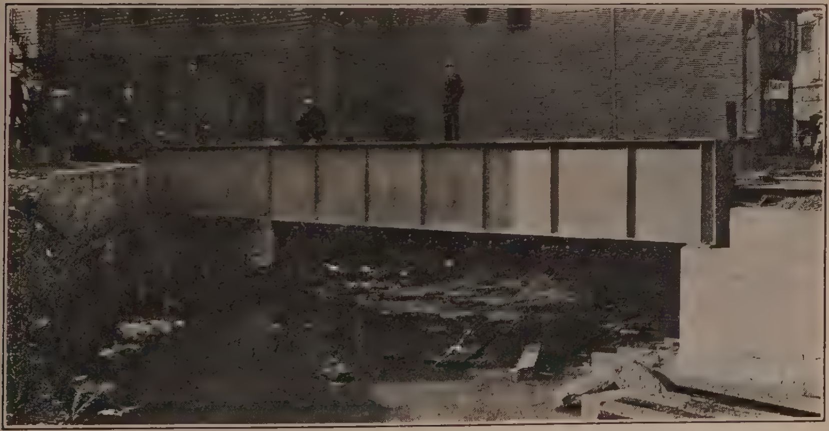


FIG. 7. — 55-FOOT PLATE GIRDER SPAN

Now that arc welding is widely regarded as a coming method which ay presently cause extensive changes in structural practice, it is time o sound a warning against its hasty or ill-considered adoption by those o whom it looks too easy. The opposition that has been faced all along he line by those who have built pioneer structures by welding has forced areful consideration of every step and has called for proof of the safety of every detail and has brought about inspection of more than ordinary thoroughness. With the recent noticeable relaxation of opposition to welded construction, with the rapid awakening of interest among steel fabricators, engineers and architects, and with the rising demand by the public that the clamor of the pneumatic riveter be stopped, there approaches the day when bad engineering or bad welding may cause something to give way. There is nothing dangerous about welding if proper control is exercised; the only danger is that which is inherent in any new method, — lack of experience on the part of those using it. The steps necessary to insure control are the following: correct engineering, schooling of welding operators, and inspection by men trained in that work. There are economies in the welding method more than ample to pay for these precautions.

WELDING TRUSSES FOR INDUSTRIAL BUILDINGS

By Andrew Vogel*

(Presented before the Affiliated Technical Societies of Boston, December 14, 1927)

The assembly of steel members into the form of trusses and frames involves two fundamentally different types of fastenings, — namely, pins and welding. The pin type fastenings can be separated into three kinds, — pins, bolts and rivets. The welding method can be divided into three distinct types, — mechanical, resistance and fusion welding.

In this paper fusion welding alone will be discussed, with particular reference to electric arc welding. It will be understood, therefore, that in using the term "welding" the writer is definitely confining himself to that form of welding which consists of striking and maintaining an electric arc between two electrodes, one electrode being a metallic rod and the other being the junction point of two surfaces to be connected. The metallic rod is melted away and deposits a fillet between the two surfaces to be connected, and in the process fuses and welds together the two surfaces immediately adjoining. With this definition it is possible to immediately confine the paper to the problem involved in welding steel trusses.

It is, however, well to mention that the problem itself would never have arisen had it not been obvious to engineers that tension members of pin-connected structures were uneconomical, due to the necessity of neglecting in design calculations the strip of metal the full length of the members which is located between and is of same width as the pins, and had there not been frequent complaints about the noise of riveting steel work. If, then, there are two important incentives to cause engineers to study the design of buildings for the purpose of applying welding, and both of these incentives are directly or indirectly measurable in dollars, we are certain that the problem will be pursued to a satisfactory conclusion.

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* Of the General Electric Company, Schenectady, N. Y.

ELIMINATION OF NOISE

The riveting of large buildings in our cities has been the source of much complaint. Boards of health and health commissioners are frequently besieged with complaints regarding the unbearable noise of the steady hammering of riveters at work. All of us have experienced the annoyance of riveting hammers, so if anything can take its place which will produce satisfactory results, even though the expense be slightly higher, we are justified in making the substitution.

SAVING IN STEEL

The reduction in the amount of steel required for trusses that are arc welded in comparison with trusses that are riveted is only a problem in mathematics. Two examples are given from designs prepared for a factory building. The first is a riveted Warren truss of 58-foot span used in one of our buildings and a welded design prepared for compari-

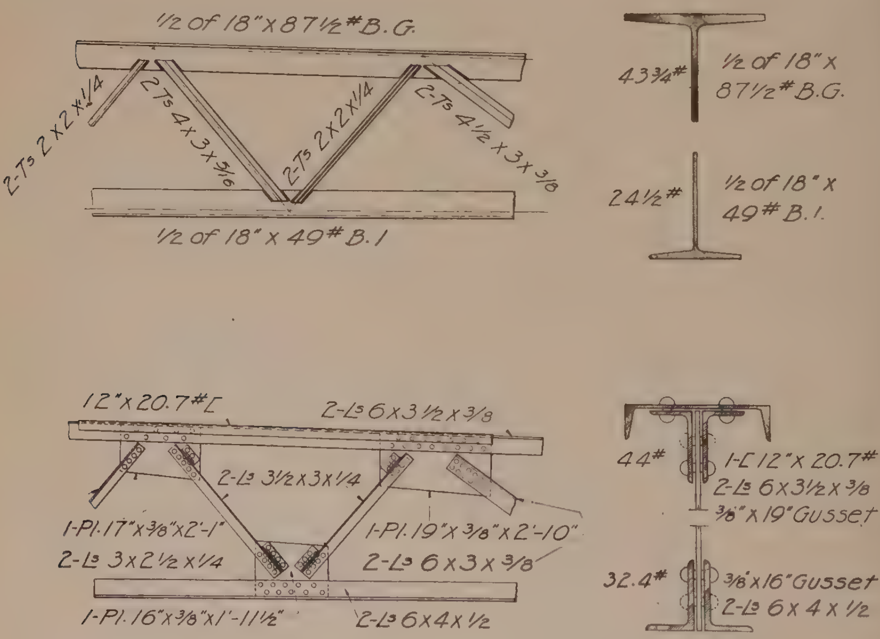


FIG. 1. — COMPARATIVE DESIGNS FOR 58-FOOT WARREN TRUSS

Upper — Welded Design
Lower — Riveted Design

son. The second is a design of a riveted Pratt truss of 80-foot span and a welded truss adopted for construction.

Calculations of the weights of these trusses indicated a saving in weight of between 12 and 15 per cent in favor of the welded trusses. Naturally these calculations indicated that engineers were justified in making a diligent study of the entire problem in order to obtain these economies in steel work both for the present and for the future. If no other benefit was to be derived except the reduction in the amount of steel required, this alone would be a sufficient incentive to develop methods of designing trusses which would not only obtain economy in material, but which would show economy in construction.

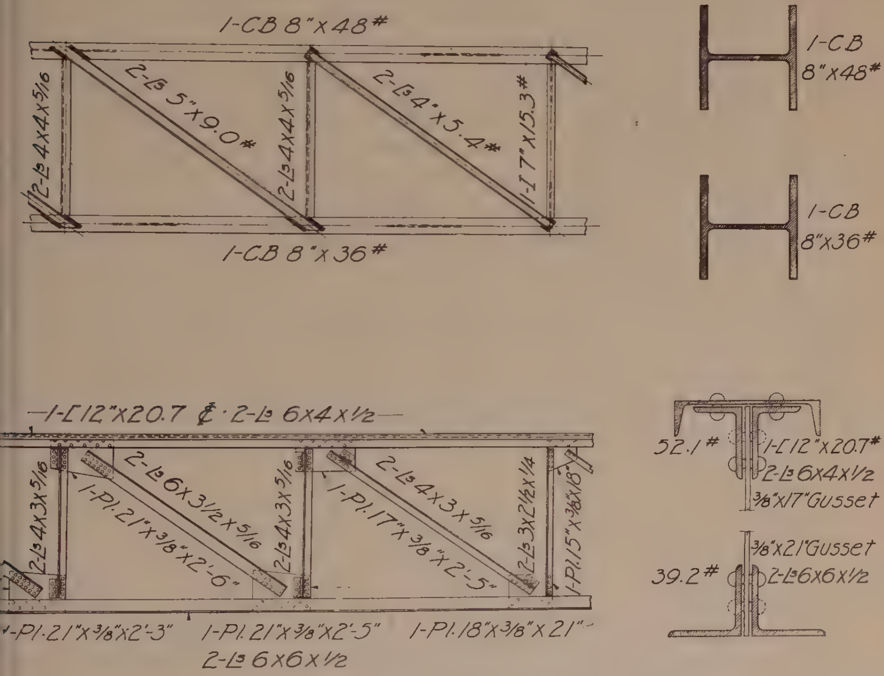


FIG. 2. — COMPARATIVE DESIGNS FOR 80-FOOT PRATT TRUSS

Upper — Welded Design
Lower — Riveted Design

Assembly and Erection Costs

It has been definitely shown, at least to our satisfaction, that the cost of welding trusses is no more than the cost of riveting trusses, and if such continues to be the case the over-all cost of welded trusses will continue to be less than the over-all cost of riveted trusses. Trusses are fabricated in the shop, where actual and definite costs can be more readily established than in the field and the work can be under closer supervision, but there has been insufficient experience to date to determine the actual cost of field work with respect to riveting *versus* welding. Experience also has not been sufficient to determine the best form of field connections where welding is to be used, while, on the other hand, the long experience we have had in bolting and riveting structures has determined very exactly the best forms of bolted or riveted connections to use. It will, therefore, be necessary for all of us to have considerable patience while this problem is being worked out.

The writer will not claim that welding is ready to displace riveting on field work, but he does claim that development to date indicates that when the technique of field work on welding has reached the high standard with respect to riveting, the cost will not only be comparable, but may even be less, with the additional satisfaction that the quiet of the neighborhood will not be disturbed by the terrific racket of the riveting hammer.

Let us also say, however, that we will not, at least for some time, entirely displace pin type connections for erecting purposes. There are at the present time no types of field connections in sight which offer any easier method of bringing members into proper position than field bolting. It may be that some type of joint not yet foreseen will solve the problem, but for the present we prefer to continue the use of field bolts for the temporary connections required when steel is erected.

Method of Attacking Problem

When an engineer desires to accomplish a definite purpose he naturally analyzes his problem into its simplest terms and then determines the fundamental principles involved. In the design of trusses the methods of calculating stresses have long been determined, and there is, therefore, nothing to say at this time on the subject. If, then, the stresses can be readily calculated, there is only one problem left, and that is to determine the actual unit stresses to be used for the various types of welds. In order to obtain data for these units the literature on the subject was carefully examined, and it was found almost invariably that the specimen itself either distorted badly or broke before the welded joint had reached its maximum capacity. Obviously, that type of test specimen was wrong. It then became necessary to design a test specimen which would fully develop the welded joint to its ultimate capacity without the specimen itself being stressed beyond its elastic limit. In other words, the welded joint must be broken before the specimen became distorted. In this way the unit stress would be determined for the welded joint and would not be affected by an entirely different problem, — that is, the unit stress in the member.

We are all accustomed to testing steel members independently of riveted joints, but for some unknown reason when welded joints were tested the specimens were not designed to actually test the joint, but more to prove that sufficient welding could be applied to completely distort or cause the member to fail. Of course this latter type of test was of no value in furnishing data for the design of welded joints. It was merely spectacular without producing unit stresses.

Tension and Compression Tests

From the information given above you will note that specimens for welding tests must be most carefully designed, and a group of twenty-four specimens were so designed for welds of 3, 4, 5 and 6 inch lengths. These specimens were in groups of three, each group designed for testing in tension and compression. In all cases, however, the welds were designed to fail in shear on a plane perpendicular to the long side of the triangular cross section of the weld. This section of the weld, being its weakest plane, is in pure shear if no secondary stresses occur at the joint, due to deflection or distortion of the specimens.

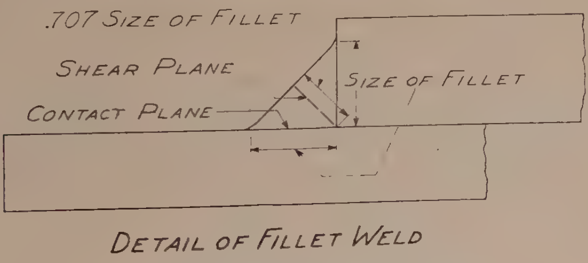


Fig. 3. — Cross Section of Weld used in Tests

Of the 96 welds in this series of tests 93 broke along the shear plane and 3 broke along the contact plane, the shear plane being defined as the plane across the triangular cross section of the weld, as mentioned before, and the contact plane being defined as the plane where the welding material is in contact with either member to be joined together.

In each of the three cases where the specimens failed at the contact plane, bits of the parent metal were torn out, showing that thorough fusion had taken place, and in these three cases the unit stresses developed were directly comparable or equal to those where failure was in shear. In order to indicate the uniformity of these tests a diagram was prepared on which each test is plotted.

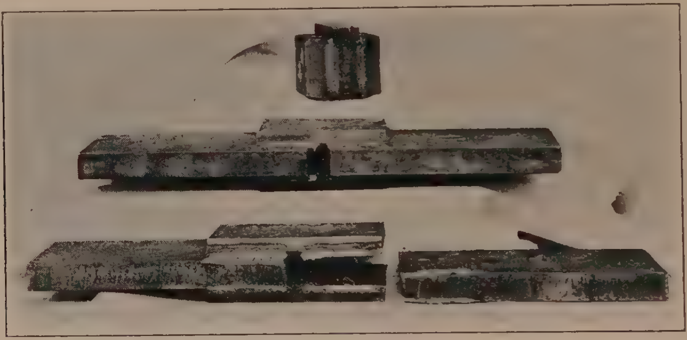


FIG. 4. — SPECIMENS AFTER FAILURE

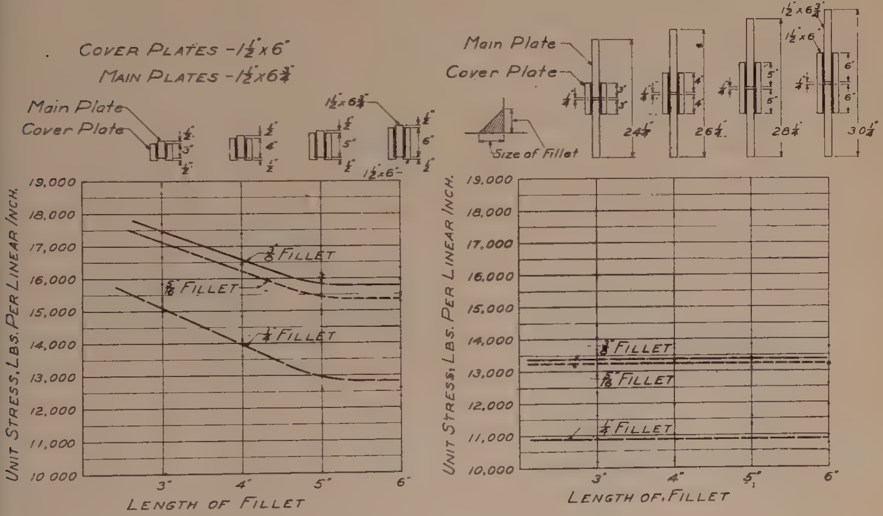
Upper — Compression
Center and lower — Tension

These groups are divided into two parts, — the compression group and the tension group. The compression group gave higher values than the tension group, and this has been explained by the fact that the compression group were short chunky specimens in which bending could not occur, due to the stresses in the specimens, while the tension group were of necessity long specimens in which bending would occur, even though the stresses were within the elastic limit.

RESULTS OF TESTS

From the tests so made it was determined that welding with a minimum contact distance of five-sixteenths inch, and a maximum contact distance of three-eighths inch, the variation being specified to allow for the inaccuracies of workmanship, permitted a unit stress of 3,000 pounds per lineal inch. The tests indicated a range of 11,570 to 14,040 pounds per lineal inch, with an average of 13,055 pounds per lineal inch for welding of five-sixteenths inch contact distance, with ten of the twelve specimens having a value of 12,300 pounds or more per lineal inch and the other two 11,570 and 11,930 pounds per lineal inch.

You will observe that basing the unit stress on the values obtained from the tension specimens alone, a factor of safety of four or better, is obtained in practically all cases. If, on the other hand, the compression specimens are considered, a factor of safety of five or better is apparent in all cases. It is, however, necessary to be conservative in any new type of design, and it was for this purpose of being conservative, together with the thought that we must not handicap a new method by too low unit stresses, that the value of 3,000 pounds per lineal inch was adopted.



COMPRESSION TENSION

FIG. 5. — TESTS OF ARC WELDED SPECIMENS

TRUSS DESIGN

You have, then, before you the two essentials of truss design, — first, the fact that the stresses can be readily calculated for the various members and joints; and second, the unit stress to be used for the design of the joints. The unit stresses used for the design of the members of the trusses mentioned as examples were, of course, those regularly used in the design of structural steel in accordance with standard American practice.

We will now turn to the development of the design of the truss itself. It was, of course, necessary to make various designs and compare them with riveted trusses in order to see what results would be obtained. We will now consider a riveted Warren type truss used in one of our buildings, and a welded design for the same truss. We will also compare the cross sections of the main chord members. Gusset plates are entirely eliminated in the welded design, and this is another element of welded design which results in economy. On the riveted truss the stresses in the members must be cared for at the joints by riveting through gusset plates. In other words, the members are not directly connected together, but are connected to another element, the gusset plate, which means that the connections are made more than once for each joint in nearly all trusses. In the design of the welded truss, however, the members are directly connected to each other, so that a unit of connecting material in the welded design is performing one unit of work, while more than one unit of connecting material is required in the riveted design in order to perform one unit of work. The comparative sections also indicate that simpler members can be used, resulting in a saving of rolling cost, handling cost, paint, and inspection.

Another comparison is made between riveted and welded designs for Pratt trusses of somewhat longer spans. The cross section of the chord members indicates that a Carnegie beam is more economical for top and bottom chords than channels and angles for top chord and angles for bottom chord, as in the case of the riveted truss. Furthermore, a study of the design of Pratt trusses indicated that angles and I-beams could be used for the compression members and channels for the tension members, and that all these members could be welded together without the use of gusset plates. The welding is symmetrical with the center line of the truss members, and the amount of welding can be directly and easily calculated from the stresses in the members.

The problem is just exactly as simple as in riveted construction. The saving in weight by using welded trusses, previously mentioned, refers to these designs, but your attention is again called to the comparative simplicity of the welded truss with respect to the riveted truss, the omission of gusset plates, and the fact that one unit of connecting material in a welded truss performs one unit of work, while more than one unit of connecting material is frequently required to perform one unit of work in riveted construction.

For the present it is desirable that welded connections should be designed as simply as possible; that the areas of welding should be concentric with the center of gravity of the members; and that all welds should be designed as shear welds. At the present time tests are being eveloped for other forms of welding connections, but until these tests re repeated enough times to determine definitely the unit values of uch connections, we have decided it is desirable to continue the simple onnections now being used.

Riveting and welding should be compared with respect to their elative economy in each particular work, and whichever proves the ore economical should be used. There is no conflict of merit between he two methods, simply the age-old conflict of economy, and whichever roves to be the more economical will survive in its proper sphere. ut certainly our experience with welded trusses indicates that this is field where arc welding is rapidly proving its utility.

Discussion of Papers of F. M. Farmer, Gilbert D. Fish and Andrew Vogel

Mr. Frank B. Walker:* We instruct our welders to have a short rc and clean surfaces. We believe that welding cannot be properly one unless the arc length is properly controlled and surfaces are clean. bout all our failures of welded seams have occurred where our suraces were not clean.

Mr. A. C. Waghorne:† I am sorry, gentlemen, that my particular ffice in the company does not make me more familiar with this operaion, but having been at our shop over Saturday and Sunday, I have ctually seen the work on the Chicopee Falls Bridge.

The main thing that struck me as one of the problems that we are o face, if we are going to cope with this new form of construction, is he present lack of proper equipment in the fabricating shops. I know ne item, namely, the chipping, has appeared to me to be a very expenive process. And, as Mr. Fish has told you, the ends of all our floor eams, and also the stringers, although I am not exactly sure on that. ave to be beveled to 45 degrees, and that in itself is quite a process. lso, as you perhaps noticed, the webs of all the floor beams have to e slotted, and that involves equipment which is not a standard part f the average fabricators' plant. The slot welding involves the slotting f the gussets, which is not a particular problem, because in every case, s you will notice, the slot is adjacent to the edge of the gusset, which nables that slot to be made rather efficiently on the average friction aw.

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* Chief Engineer, Eastern Massachusetts Street Railway Company, Boston, Mass.

† Of the Palmer Steel Company, 44 Bromfield Street, Boston.

Of course the process of fabrication of this bridge is practically complete, and I believe deliveries are being made, and an erection program, as far as it has been called to my attention, will be somewhat as follows: I believe they will start putting the bridge together, bolting it up on one side of the canal, as Mr. Fish indicated, immediately. The actual completion of the assembling will not take place until the first of the year, and soon after that the final field welding will start, and only after it has been all lined up and plumbed and thoroughly bolted and checked in every respect.

As far as I can see now, it seems as though welding in bridge construction has possibilities, although we have no records of costs as yet.

I should say that if any of you gentlemen are interested in following the job from the field end, which is perhaps the most interesting part of it, — that is, the actual examination of the structure during the stage of the welding, — I would be very glad to have you get in touch with me, and I will make it a point of knowing the times at which it will be most advantageous for you to go up and look over the structure.

MR. ANDREW VOGEL:* The trusses with which I illustrated my talk were from the Philadelphia building. This building was the cause of a great deal of research and considerable negotiations with the city of Philadelphia. The building authorities in Philadelphia were rightfully very conservative in their attitude towards applying welding, especially on so large a scale. The building in question is about 140 by 600 feet in plan, involves some 20 trusses of about 80 feet span, 20 of about 58 feet span, and seven of about 72 feet span. The city required that the design be so prepared that they could easily understand the design as it developed. You will, most likely, have noticed all through my talk that I was pleading for simplicity of design. It is most important that everything designed in the building line at the present time be as simple and direct as possible, so that the building inspectors will understand readily what you are talking about. The average building inspector is not a trained structural engineer. He has only a general knowledge of building construction as a whole.

The city of Philadelphia was fortunate in having on their staff men we could talk to very freely and who understood what we were driving at. The process of obtaining a permit took a matter of several months, because it required acquainting officials with the tests made, inviting them to Schenectady and showing them tests, and also showing them methods of welding and methods proposed for testing the construction. The latter part of this week we expect to test some of these rge trusses. When the permit was granted, it was granted on the basis ' the tests shown you today, and it was granted with the understanding ıat it was an experimental permit only; that is, this building could be uilt, but other buildings could not be built like it without a special ermit.

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* Of the General Electric Company, Schenectady, New York.

We have had contact with a couple of other building departments, ıd they took exactly the same attitude, — they wanted to be shown. nd the simpler the process of showing, the easier they seemed to under- and. So far practically all building departments are approaching weld- g with an open mind, and in Schenectady, where we have done a great eal of welding of structures, the Schenectady Building Department ants permits unhesitatingly. In most cities, I am sure, there will be difficulty in obtaining permits, provided the design is simple and raightforward and can be readily understood. In other words, do not tempt anything complicated, because I doubt very much whether the verage building department will understand it.

Question: Mr. Vogel touched slightly on what I wanted to ask, ıd that is, if there has been any method developed by which structural ıgineers who are not perhaps familiar with the process can determine ı inspection whether or not the weld is satisfactory. On riveting it as been very necessary to watch the riveting gang and see that they the job right, although we all know it can be done right. Now, ad- itting that the welding job can be done properly, is there a method at ıe present time developed whereby an engineer not familiar with the rocess, or not familiar at the present time, can become familiar in such way that he can make satisfactory inspection and be reasonably sure reliability?

Mr. F. M. Farmer:* I am afraid, Mr. Chairman, you are at last oing to uncover my great ignorance of this subject. I hoped to get away ith a bluff, but I suppose I can't expect to do that. As a matter of fact, y normal vocation is far, far removed from welding, so that these uestions of details will have to be answered by the experts.

While we have not as yet developed an effective so-called non- estructive test of the completed weld, we feel that just as satisfactory ork can be done as with any other method of joining metals if we have ompetent supervision. Now, you have all seen what is such an im- ortant element in this whole development, namely, a proper design, — design which has been developed to use the welding process in the most ficient manner. That having been done, and having the proper mate- als, the next thing is, of course, to see that the work when it is com- eted is satisfactory.

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* President, American Welding Society, New York.

Well, we have used so far the same general type of process in accomplishing that which we use in riveting, that is, competent supervision. First, you must have welders who have the right craftsmanship attitude for the job; then you must have competent supervisors, — supervisors who have been through the "mill of experience" and recognize good welding while it is being done. Constant and competent supervision is the keynote of the situation.

Mr. Vogel: In Mr. Farmer's paper he showed an illustration of a perfect weld. That appeared in the lower corner of a diagram. In my paper I showed a cross section of a typical weld, and if you recall the diagram you will recall that where the contact surfaces adjoined the sloped surface of the fillet weld there was a sort of concave joint. Every weld we have tested so far, starting with the clean surfaces, and made with short arc, sufficient current, and concave form of fillet, has been a satisfactory weld.

Possibly the best definition of inspection of welds is given in a short article by Lewis E. Moore in the Engineering News-Record recently (April 21, 1927, Vol. 98, page 657). I do not believe anything can be added to his discussion of a good weld.

Mr. Farmer: I might add that one of the current activities of the American Welding Society, which we hope to be a very important one in this great industrial development, is the working out of what we call a procedure control. In other words, we are developing standards which will, we feel, insure a high quality of workmanship. Among many other things it will include qualifying tests for welding operators. It is going to be a rather extensive piece of work, but we think it will do a great deal to establish a minimum acceptable quality of welding.

Question: Should we take off the mill scale before resistance welding?

Mr. Vogel: We have not used any resistance welding for structural work, so I cannot answer that question. But on structural work where we have used arc welding, if the mill scale is loose, it can be scraped off, or if it is hard and tight, we go ahead, as the torch will cut through the mill scale almost instantly. I have never noticed any difference in the test specimens. In fact, I recall that two or three of the test specimens did have scale on them, and I did not see any difference in the results in the testing machine. I doubt very much if a tight mill scale has any effect whatever on the weld.

Mr. Walker: There are two different types of field tests, — one, the breakdown test, and the other is the visual test.

Our experience has brought out two general indications which may e looked for in a seam weld: one is whether the steel is spattered, which Ir. Fish very plainly stated was due to the fact that the arc was too ng; and the other is that the welded metal will stay bright for a very ng period when the heat regulation was correct. Where the arc is too ot the seam will turn a rusty red in a very few minutes.

APPLICATIONS OF PROJECTION AND MULTIPLE WELDS

By W. T. Ober*

(Presented before the Affiliated Technical Societies of Boston, December 14, 1927)

It is perhaps well to state at this time, in order to avoid any misunderstanding, that this paper deals not with electric arc or gas welding, but rather with electric resistance welding.

A broad definition of electric resistance welding is the uniting of metal parts which have been raised to a welding temperature as the result of the passage of a large volume of electric current through that portion or those portions of the parts which are to be united.

Resistance welding is divided into several classes, the three principal ones being spot welding, generally thought of in connection with the joining of overlapping sheet metal parts which otherwise would be fastened by rivets or bolts; butt welding, which is the welding of parts end to end or edge to edge; and seam welding, which might be termed a continuous spot weld along the overlapping edges of sheet metal parts. It is spot welding, or, rather, particular forms of spot welding, with which this paper deals.

Since the discovery of resistance welding, practically all spot welds have been made by using a spot welding machine equipped with two so-called pointed copper electrodes or welding dies, the actual size of the point depending upon the thickness of the material to be welded, the capacity of the welding machine used, size of the spot weld required, etc. In this method the pointed electrodes serve as the agent for localizing and concentrating the flow of current to the mass of material directly between the electrodes, and, of course, only one spot weld is made for each cycle of operation of the welding machine.

Projections on One of the Parts

Quite a number of years ago it was discovered that by punching a projection on one of the two parts to be welded this projection would serve as the agent for localizing the current flow, and therefore determine he point of weld. Also, that the size and shape of this projection determines to a great extent the size or area of the weld, and thus the trength of the weld. Also, that by using this projection it was no onger necessary to employ a pointed electrode which, of course, wears away fairly rapidly, but rather that large, flat-ended electrodes could be used which would last almost indefinitely.

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* Of the Thomson Electric Welding Company, Lynn, Mass.

One other advantage of the use of projections was found to be in he welding of scaly material. Scale or rust is, of course, an insulator, and it is oftentimes very difficult to force the necessary amount of current for making a weld through this scale when using the ordinary electrode, but by forming a projection on one of the parts, the forming operation breaks up the scale on the projection, and this projection, being fairly pointed in turn, breaks through the coating of scale on the other part when pressure is applied through the welding electrodes.

For a number of years this method of projection welding was employed only in a small way, and no attempt was made to weld more than one projection at a time. As the demand for increased production on welded parts grew, experiments were made to determine the possibility of making several spot welds in one operation. At first these experiments were conducted along the lines of using a series of pointed copper electrodes, but only a fair degree of success resulted, as the same old condition of rapid wear of pointed electrodes was encountered, and as the various points of a multiple pointed electrode did not wear uniformly, a condition was reached after a comparatively short period of operation where, due to non-uniform contact between the various points of the multiple electrode and the work, the results were non-uniform welds.

Experiments were then conducted relative to the possibility of using large flat electrodes and welding together parts which, instead of having only one projection, had a number of projections. These experiments immediately proved successful.

It does, of course, require a welding machine of larger electrical and mechanical capacity to make several welds in one operation than is required for making single welds. For this reason and also because of the lack of knowledge of how projection welds could be used to advantage on various classes of work, this method of multiple projection welding was not used commercially to any great extent until comparatively recently.

Within the last three or four years the Thomson Company have designed and developed a number of more or less special welding machines to be used particularly for making multiple projection welds.

There have also been developed machines for making multiple welds on parts, the inherent shape or form of which is such that the parts themselves supply their own projections.

A typical illustration of this is the welding, in one cycle operation, of a number of wires to one or more wires which cross at right angles, as in wire refrigerator shelves, stove oven racks and articles of a similar nature. Another application of this form of welding is used in the manufacture of grating made from a series of flat rectangular bars stood on edge, to each bar of which is welded in one operation a round or twisted bar laid at right angles to the longitudinal axis of the strips.

This method of projection or multiple welding is being successfully used in the automotive field in the manufacture of various automobile body parts, such as door frames, window lifters, four-wheel brake parts, shock absorbers, and on any other article more or less flat or regular in shape and which requires several welds.

Limitations of Projection Welding

Experience has taught us that the use of projection welding is not always satisfactory if the part carrying the projection is made from material thinner than 16 or 18 gauge, unless the projections are spaced very close together. This is because a projection punched on thinner material does not have sufficient mass or strength to retain its shape long enough after welding current and pressure are applied to serve its purpose of localizing the current flow.

There is, of course, also a limit to the number of projection welds which it is practical to make in one operation, this limit being determined principally by the area over which the projections or welds are distributed, for, as is readily understood, it is necessary that the welding current distribute itself uniformly between the projections or points at which welding is to occur, and that if the projections are spread over too large an area or surface, difficulties will be encountered in obtaining uniform pressure or contact between the large flat surface of the copper electrodes and the work, resulting in non-uniform distribution of current

In the making of multiple projection welds on sheet metal parts not less than 18 gauge in thickness, it has been found that the area over which the projections are distributed should not exceed 30 to 35 square inches, and that the greatest distance between any two projections in this area should not exceed 10 inches.

Two to twelve projection welds on sheet metal parts in one operation are now being made as part of the daily production in many factories. Ten to twenty-five, and even thirty, welds in one operation are being nade on parts of such form that no projection is required, such as wire oap dishes, oven racks, subway grating, etc.

The question of whether or not it would be advantageous to use rojection or multiple welding on any article now being welded by the ingle spot method can best be determined by careful investigation of ll conditions surrounding the method of manufacture of this article, he production required, the shape and size of the parts, and the material rom which they are made. The process has a wide field, but is not yet t the point where all of its possibilities or limits are known.

Any one interested in the possibility of applying projection or nultiple welding to any article now being welded by the single spot nethod should get in touch with one of the manufacturers of resistance velding equipment, any of whom would be glad to share their knowledge f the process.

RECLAIMING A CAST-IRON WATERWHEEL CASING

By C. W. Babcock *

(Presented before the Affiliated Technical Societies of Boston, December 14, 1927)

"Weld cast iron by the electric arc? It can't be done!" Many statements of this kind have been made. Sometimes this is right, sometimes not. It depends on a number of factors.

Because of the more or less general understanding among the engineering fraternity that cast iron is an insurmountable barrier which electric arc welding cannot cope with, it was thought that this paper might help to revise the impression. It may even suggest to some one who is confronted with considerable cast-iron parts maintenance a means of overcoming annoying difficulties.

In spite of the inroads of steel of all kinds in the fabrication of machinery, cast iron will continue to be used for a long time to come, and there will be breakage and needed repairs as long as it is in commercial use. It is because of the great amount of possible welding to be done on this metal that recent years have seen increased interest in it. Although it is possible to weld cast iron, this does not mean that it should always be done by the arc. Each job must be decided on its merits.

There is not sufficient time to enter into a discussion of the welding of cast iron by the electric arc, nor is this the writer's purpose now. What follows merely relates one instance where the elements in the problem were such that arc welding could be used to advantage, and did accomplish the desired end. The present state of the art, in other words, was such that what ten years ago might have given a different result offered no real obstacle today.

About two and a half years ago, a plant in New England found it necessary to shut down a waterwheel because of water leakage through the casing. This was an old horizontal wheel which had been patched up from time to time till it was no longer in suitable condition to oper-

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* Sales Engineer, Westinghouse Electric & Manufacturing Company, Boston.

ate. The wheel ran under about 150 feet head, so the pressure inside the casing was about 65 pounds per square inch.

Either an entirely new casing would be required, or, what at first was considered impossible and expensive, repairs were needed. The matter of a new casing was taken up with the wheel manufacturer, and it was found that it would cost approximately $1,000 and could not be delivered for three months. The element of time was the more important, as high water was expected in about three weeks, and it was essential to have the wheel available as soon as it could be used.

Here then was a situation which no factory superintendent looks forward to with pleasure. Orders must be filled, and this involves use of machinery. Repair, or buy a new waterwheel casing? Which?

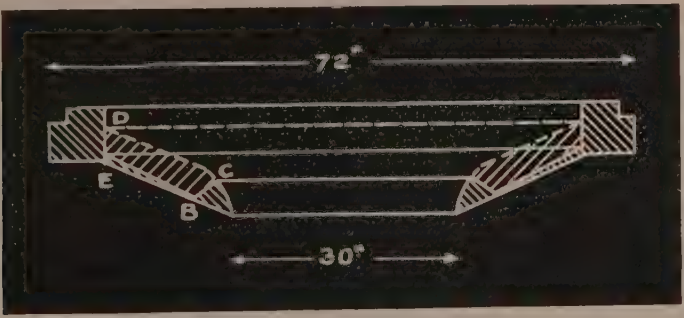

Fig. 1. — Cross Section of Casing

The bookkeeping figures in this instance would show that this wheel had long ago been charged off and that a large expenditure of money on it might therefore be unwise. But the time factor could not be altered.

So the master mechanic and blacksmith, who also did the gas welding, looked the job over carefully, and the latter decided it was not feasible to weld it by the torch. The casing weighed about a ton and it would probably be necessary to build an oven or furnace in which it could be heated thoroughly before and during welding, and even then it was a questionable matter. Some one mentioned arc welding, but the blacksmith shook his head and said "No use." The superintendent and master mechanic were unconvinced, however, and, as this offered a possible loophole, decided to try the experiment. If it failed, they were little worse off than to begin with.

This is, then, where we came into the picture. It was a cold one, too, for a waterwheel room in the middle of winter, in a plant in northern

New England, is not the most ideal spot to spend many lingering minutes.

Fig. 1 will show a cross section of this casing. During years of operation the outboard and thrust bearing had worn gradually and the wheel or runner moved laterally till it touched the casing and wore away a section about 10 inches wide and 1 inch deep entirely round it. In one place the casing was worn through completely for a considerable distance, and in other spots it was only from $^1/_{16}$ inch (or less) to ¼ inch thick. A patch had been placed over the weakest parts.

The dotted line shows the original limits of the casing, and the section C. B. E. D. was the part worn away by the runner. At the point B the casing was very thin, and in places actually entirely worn away. At point E the remaining iron was about ¼ inch thick, and it tapered down from here to B.

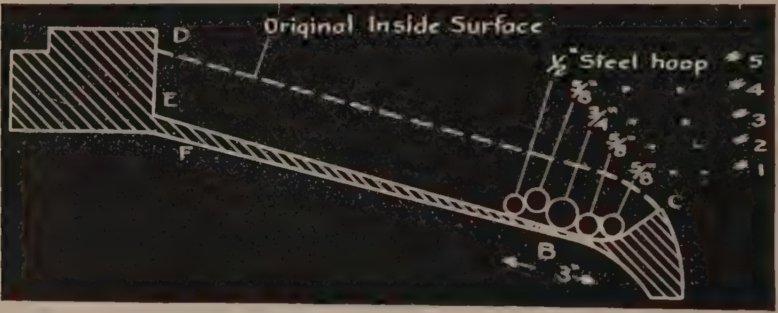

FIG. 2. — CROSS SECTION SHOWING HOOPS USED FOR REINFORCING

Because of the extreme thinness of the iron near the inside radius of the worn section, that is, at B, in Fig. 1, it was manifestly impossible to weld, or deposit metal, on the casing itself. The arc would have burned through as fast as established, and it would have been cutting instead of welding. So this space was bridged by a series of steel rings or hoops welded together and to the casing, and then the remaining area welded in.

It will be noted that this was in fact a sizable piece of iron, and is evidence of the origin of the blacksmith's reluctance to reclaim it by gas welding.

Fig. 2 is a cross section through one-half of the casing, showing where the steel hoops were placed. They cover the thinnest part of the casting, or a space of about 3 inches.

Hoop No. 1 was ⅝-inch diameter rod and was welded to the neck of the casing; then hoop No. 2, also ⅝-inch diameter, was placed outside No. 1 and welded to No. 1 across the top; hoop No. 3, ¾-inch diameter, was then put in place and welded to No. 2. Hoop No. 5, ½-inch diameter, was then placed at such a distance from No. 3 that hoop No. 4 would, when finally put in its place, be raised up from the cast iron; hoop No. 5 was then welded to the casing on outer side. This was done to prevent No. 5 from pulling or shrinking from the cast iron, as it might have done if first welded to No. 4. Hoop No. 4 was then dropped into place and welded to No. 3 and No. 5.

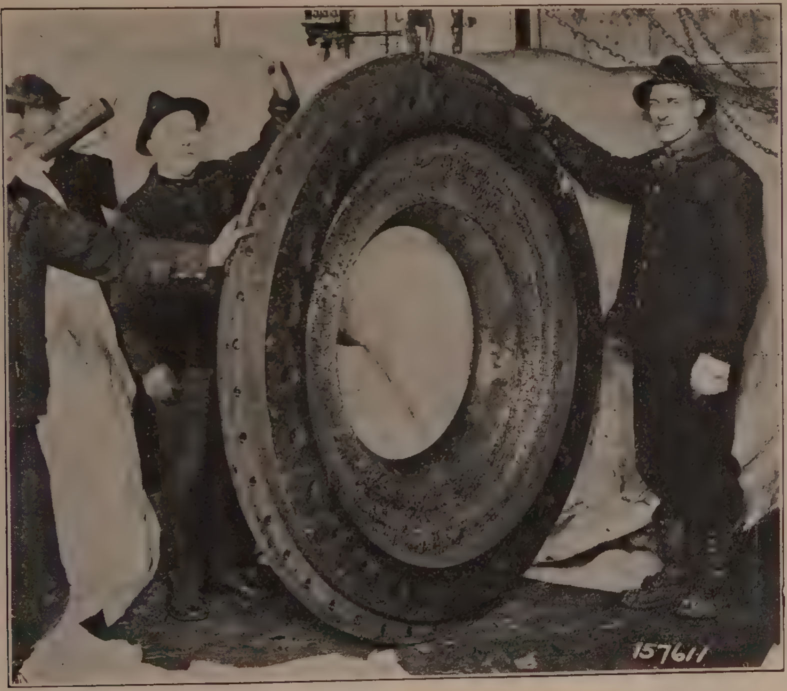

Fig. 3. — Casing after Completion of Work

A small piece was cut out of each hoop before welding to allow for expansion and the gap filled in later. These gaps were staggered. This then made a strong bridge over the thin section, and the whole remaining area was welded in without any great amount of trouble.

While welding directly on the cast iron, the welder ran a bead of only one or two inches at a time in one spot, and a helper then immediately peened this with a hammer, to stretch it and avoid porosity as much as possible. The first layer of welding to the cast iron was done with a special grade of welding wire for cast iron. Succeeding layers were put on with ordinary steel welding wire.

After the welding operation was finished a portable grinding wheel was rigged up and the high spots merely ground off the welded section. A strictly smooth surface was not required. The re-enforcing patch on the outside of the casing was left in place, as there was no object in removing it.

This repair was made in one week, with the services of two men, the welder and helper who did the peening. About 250 pounds of welding wire were consumed and the total cost was approximately $175. As mentioned before, the time element outweighed cost in this job. The latter was really insignificant. This is one of the attractive features of welding, for even if a permanent repair cannot be made, at least temporary jobs can frequently be done to allow resumption of operations.

In this case, however, no future repairs were needed. The wheel has been in continuous use since and apparently will deliver many years more of service, in so far as this welding operation is concerned.

Welding, in short, for plant maintenance should be looked upon as a form of insurance. A sprinkler system is costly and may never be called on to act, but most plants have one. Likewise, an arc-welding machine may save many hours of shut down, and its field of utility is constantly enlarging.

ATOMIC HYDROGEN WELDING PROCESS

By P. Alexander*

(Presented before the Affiliated Technical Societies of Boston, December 14, 1927)

The phenomenon of dissociation of molecular hydrogen at high temperatures into the atomic state was discovered by Dr. I. Langmuir during his studies of the laws of heat losses from a heated tungsten filament in hydrogen at low pressures. Dr. Langmuir observed that above certain temperatures, the heat losses instead of being proportional to 1.9th power of the absolute temperature, are proportional to a much higher power which increases with temperature.

The following studies of this phenomena established that these abnormally high losses are due to the dissociation of molecular hydrogen into the atomic state. Step by step Dr. Langmuir discovered the temperatures of dissociation, degree of concentration of the produced atomic hydrogen, the energy absorbed by the dissociation, the chemical properties of the atomic hydrogen and the thermic effects produced by recombination of the atoms into molecules.

The atomic hydrogen possesses many remarkable properties which have been studied in the last few years by several investigators. Many chemical reactions impossible with molecular hydrogen take place when that gas is in the atomic state. The most stable oxides can be reduced into the metallic state. Substances which are usually considered as the most refractory materials can be melted by the flames of atomic hydrogen. And certain hydrogen compounds which formerly could be produced in very small concentrations, now may be obtained in 100 per cent concentrations. There are two methods of producing atomic hydrogen.

One discovered by Dr. Langmuir is by increasing the speed of the thermal agitation of hydrogen molecules until the forces between the two atoms composing the molecule are not sufficient to hold them together. They spring apart and by doing so absorb large amounts of energy from the source producing that thermal agitation. In this method all molecules subjected to the high temperature are being acted upon simultaneously. This is (if we can use such a term here) a "mass production."

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The other way of disrupting the hydrogen molecule is by hitting it with a heavy atom, moving with high velocity. In this method the hydrogen molecules are dissociated one by one and only when shot with a swiftly moving atom. Using again a shop term, we can call it a "piece work." However, Dr. Langmuir developed the first method which permits the production of atomic hydrogen in high concentration, which permits the use of atomic hydrogen not only as a special chemical reagent but also as one of the most remarkable agents for transmission of thermal energy. To accomplish this, it was necessary to produce the atomic hydrogen not inside of a vacuum container, but in the open air. The method adopted by Dr. Langmuir consists in blowing a stream of molecular hydrogen through an electric arc maintained between two tungsten electrodes.

The temperature of the arc core is sufficient to produce complete dissociation of the whole mass of the gaseous layer in contact with it. The produced atomic hydrogen diffuses rapidly away from the arc core and recombines in the cooler regions into the molecular state, forming an extremely hot flame of a single gas which burns without oxygen. The evolved heat, of course, is the energy previously absorbed from the arc. It was found that the heat of formation of molecular hydrogen is equal to 98,000 calories. In other words, when the atomic hydrogen recombines to produce one cubic foot of molecular hydrogen (measured at N. T. P.), the amount of heat produced is 455 B. t. u. This quantity is greater than that obtained by the combustion of one cubic foot of molecular hydrogen in oxygen. In the last case the amount of evolved heat will be only 316 B. t. u.

The greatest advantage of the atomic hydrogen resides not in the amount of energy transmitted but in the high potential at which that energy is delivered. In other words, the remarkable property of the atomic hydrogen is the temperature of its flame. Dr. Langmuir's calculations show that this temperature is at least 3,717 deg. cent. One of the experimental confirmations of these conclusions is the fact that tungsten, the metal with the highest known melting point, can be melted in the atomic hydrogen flame but not in any other flame.

The importance of the temperature of the flame can be illustrated by the comparison of two combustible gases; one of which is acetylene and another is propane. The amount of energy produced by combustion of one cubic foot of acetylene is 1,456 B. t. u. The corresponding value for propane is 2,465 B. t. u.

In spite of much lower heat capacity of acetylene, the temperature of its flame (about 3,000 deg. cent.) is higher than that of propane (about 2,100 deg. cent.) and the result of it is that the welding with that gas is much faster than with the latter.

One of the practical applications of the atomic hydrogen flame is for welding of metals.

In this field it has received lately numerous applications on account of its two properties especially valuable for welding work, namely, the extremely high temperature of the flame and the reducing properties of the gas forming that flame.

As a welding tool the atomic hydrogen torch must be compared with the oxy-acetylene torch. It has similar characteristics in that the most of the energy is produced in a comparatively small inner cone or fan where extremely high temperature is attained. This inner hot zone is surrounded by the flame of reducing gas with temperatures gradually falling to that of the outer mantle of the flame where the recombined molecular hydrogen is burning in contact with the air. The temperature of that part of the flame is something like 1,000 deg. cent.

This gradual change of temperatures gives an extreme flexibility to the atomic hydrogen torch. It insures a perfect control of speed of welding and of the temperature of the molten metal in the weld. This last factor is of a paramount importance for welding in hydrogen atmosphere. This gas is only slightly soluble in molten iron just above the melting point. But with a rise of temperature its solubility increases very rapidly. When the molten iron is overheated, it will absorb at least fifteen times its own volume of gas (measured at N. T. P.). During the solidification most of that gas will be precipitated out, and unless special precautions are taken, will form numerous blow holes.

However, if the welder follows the right technic by forming only a shallow pool of molten metal which insures a low temperature of the molten iron, hydrogen will be prevented from going into solution and the resulting weld will be perfectly free from gas pockets.

The atomic hydrogen torch embodies in itself all the necessary conditions not only to transmit from the arc into the plate any desired amount of energy, but also to do it at a very high speed. The high speed of recombination of the atomic hydrogen into the molecular state is determined by the steep gradient of temperatures and also by the catalytic action of the metal in the weld.

This recombination of the atomic hydrogen at the surface of the liquid metal in the weld to a certain extent replaces the oxidation reaction always present when the welding is done in air. This reaction supplies the necessary auxiliary heat to keep the surface of the solidifying metal in the molten state long enough to permit the absorbed gases to escape freely.

The a-c. arcs used in the atomic hydrogen process are usually two or three centimeters in length, bent in the shape of a fan between two tungsten electrodes placed to form a "V." The voltage drops at the surface of the electrodes, which correspond to anode and cathode drops in d-c. arcs, are equal to about 18 volts each. With the usual arcs of about 100 volts, the 36-volt drop at the surface of the electrodes, therefore, represents one-third of the total arc voltage, so that two-thirds of the energy absorbed in the dissociation of hydrogen into atomic state comes from the long arc core. The usual arc voltage is about 100 volts and the open circuit voltage of the welding circuit is seldom less than three or four times that value. The energy absorbed by the weld, of course, is that which comes from the arc; the atomic hydrogen plays the rôle only of an exceptionally efficient transmitter.

The energy evolved by burning the molecular hydrogen in contact with the air serves only to raise slightly the temperature of the plate outside the weld, but does not affect appreciably the weld itself. Most of that energy is radiated into surrounding space.

OF GENERAL INTEREST

PRACTICAL APPLICATIONS OF WELDING DISCUSSED

Subject Well Covered at All-Day Meeting of Affiliated Technical Societies of Boston

Practical applications of welding were discussed at the all-day meeting of the Affiliated Technical Societies of Boston on December 14, 1927. The large attendance indicated a widespread interest n the subject.

The rapid advances in the science of welding during recent years have made this subject an increasingly important one to the engineer in almost every branch of the profession.

Mr. Frank B. Walker, chief engineer of the Eastern Massachusetts Street Railway Company, presided at the mornng session which was held in Chipman Hall, Tremont Temple. Three papers were presented at the morning session, as ollows: "General Principles of the Various Welding Processes," by F. M. Farmer, president of the American Welding Society; "Examples of Arc Welded Steel Construction," by Gilbert D. Fish, conulting engineer of the Westinghouse Electric and Manufacturing Company; and "Welding Trusses for Industrial Buildings," by Andrew Vogel, of the General Electric Company.

At the close of the morning session a uncheon was held at the Boston City Club, under the auspices of the New England Water Works Association.

The afternoon session was held in the auditorium of the Boston City Club, with Robert Spurr Weston of the New England Water Works Association, presiding. Five papers were presented at this session, as follows: "Pipe Line Welding from the Oxy-Acetylene Viewpoint," by Le Roy Edwards, of the Air Reduction Sales Company; "Pipe Welding and Other Recent Developments in Welding," by D. H. Deyoe, of the General Electric Company; "Thermit Pipe Welding," by Robert L. Browne, of the Metal and Thermit Corporation; "Replacing Castings by Steel Elements Cut to Shape by Automatic Shape Cutting Machines," by Dr. A. Krebs, of the General Welding and Equipment Company; and "The Metallurgy of Welding-Wire," by C. A. McCune, Director of Research of the American Chain Company.

Between the afternoon and evening sessions a dinner and smoker was held at the Boston City Club. This was followed by the evening session, at which Lewis E. Moore, Chairman of the Affiliated Technical Societies of Boston, presided. Four papers were presented, as follows: "Unit Stresses and Reliability as Applied to Structural Welding," by Fred T. Llewellyn, representative of the American Society of Civil Engineers on the Joint Structural Welding Committee;

"Applications of Projection and Multiple Welds," by W. T. Ober, of the Thomson Electric Welding Company; "Reclaiming a Cast-iron Waterwheel Casing," by C. W. Babcock, of the Westinghouse Electric and Manufacturing Company; and "Atomic Hydrogen Welding Process," by P. Alexander, of the General Electric Company.

The Siphons at the Bartlett's Ferry Dam

By T. B. Parker[*]

This article is intended to describe a siphon spillway which was installed on the crest of the dam on the Chattahoochee River at Bartlett's Ferry, Georgia, constructed by Stone & Webster, Inc., in 1925–26 as a part of a hydroelectric development for the Columbus Electric and Power Company.

The reservoir level behind this dam is to be maintained at nearly constant elevation during all conditions of river flow except for the low stages, which require draft from storage. For controlling the level during flood stages, nineteen crest gates, each 25 feet wide and 21 feet high, are provided, having a capacity of about 9,000 c.f.s. apiece.

With the completion of a third 15,000 kw. generating unit now being added to this development, the water capacity of the station will be between 5,500 and 6,500 c.f.s. Since for about 80 per cent of the time the flow of the river does not exceed 9,000 c.f.s., it is desirable to have during this period some convenient means of controlling the reservoir level without opening the large gates. The siphons were installed for the purpose of providing automatic regulation of reservoir level during ordinary high water, and to make unnecessary the continued manipulation of the flood gates during large floods.

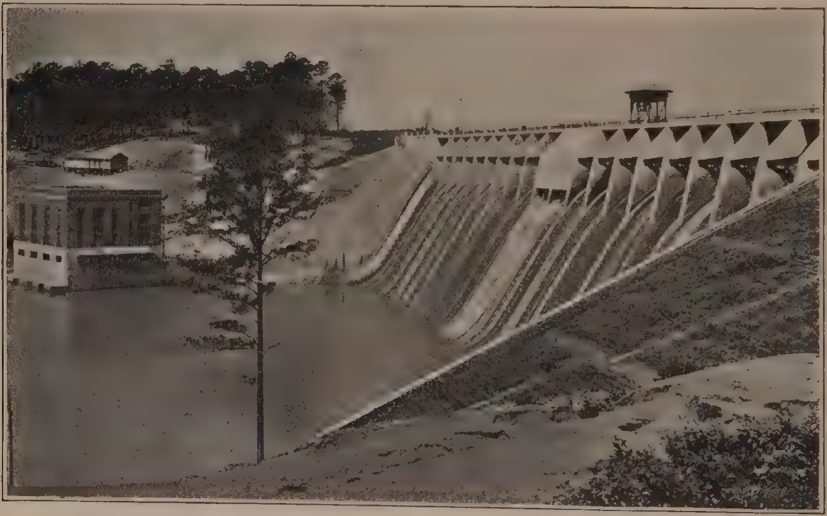

FIG. 1.—POWER HOUSE AND DAM

The advantage of a siphon spillway is its economy in length of crest. For small epths of overflow it will pass considerbly more water than an open crest of he same length. It is a simple strucure, without moving parts, and is free rom the mechanical difficulties which ometimes attend such devices as balnced flashboards and float operated ates. The ordinary siphon spillway onsists of a short crest discharging into closed chamber leading to the downtream face of the dam. A small overow partly exhausts the air from the hamber, which induces a larger overow, until the passageway flows full. t is then operating under a total head hich is equal to the vertical distance om pond level to exit of siphon. As the ond level drops, the suction is broken y uncovering an air vent placed at the esired elevation, and the flow ceases.

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[*] Hydraulic Engineer, Stone & Webster, Inc., Boston, Mass.

The reservoir area at Bartlett's Ferry s about 5,700 acres, giving 550,000 kw.-r. of storage for the top foot of drawown. On account of the considerable alue of the storage, it is desirable to ecure as close regulation as possible. his means that the siphons must prime nd break within a small range of vercal height.

The profile adopted was designed to rime with a minimum depth of flow ver the siphon crest. The upper leg of ne siphon is inclined backwards at an ngle which forces the water in falling to ass from the upstream side to the downream wall of the waterway. This fallg sheet of water entrains the air and rries it into the pool below, thus gradually lowering the pressure in the siphon amber, which in turn produces a eater flow over the crest. A nose of ncrete masonry projects downward to the pool, forming a seal which preents the return of air into the upper amber. The lower leg of the siphon given a shape which discharges the ater nearly parallel to the face of the illway.

This design is in general similar to other siphons which have been built in this country and elsewhere, except that the profile has been made unusually tortuous in order to insure the quick priming action which is so essential in this case. Four sections of siphon spillway were installed, each having a throat 4′ 0″ high and 11′ 3″ long, and estimated to have a capacity of about 1,000 c.f.s. each, or a total of 4,000 c.f.s. This size is well within precedent, as siphons having much larger throats are in successful operation.

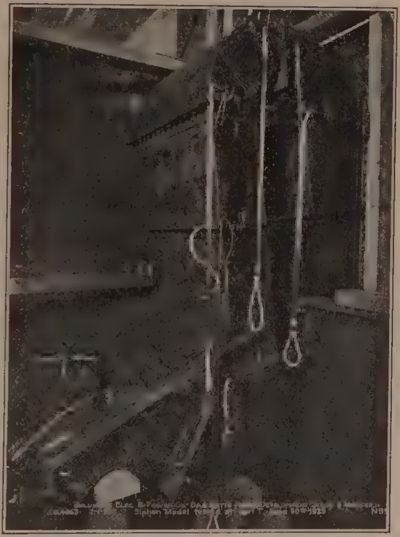

FIG. 2.—SIPHON MODEL

To stabilize conditions as much as possible for flows less than full capacity of plant and siphons, the four siphon panels were constructed at elevations differing from each other by one inch, so that the different units prime successively as the water rises.

In order to check the calculated performance of the siphons, tests were made on a model with dimensions one-fifth of full size. This model was constructed of steel plates, stiffened with light steel angles, and was set up in the testing flume of the Massachusetts Institute of Technology. Arrangements were made to measure the priming head and total discharge, and gages were installed to indicate the pressure head at various points along the axis of the siphon.

By means of the gage readings at various points it had been hoped to define a hydraulic gradient through the siphon model, and thus determine the loss of head at bends. This was found impracticable, however, on account of the great variation in velocity and consequently in pressure head at many of the cross sections, making it difficult, if not impossible, to obtain the correct average total head at any given section.

The discharge from the siphon model as measured over a weir was found to be 18 c.f.s., which on the basis of a head equal to the vertical distance between headwater and center of discharge section, shows an efficiency of about 55 per cent. The ratio between the discharge from two similar siphons whose linear dimensions have the ratio "S" is $(S^{\frac{1}{2}}) \times (S^2) = S^{\frac{5}{2}}$, or, in this case, $(5)^{\frac{5}{2}} = 55.9$. This ratio is obtained by considering the discharge velocity as proportional to the square root of the head (a linear dimension) and the area of the siphon as proportional to the square of its linear dimensions. If the discharge capacity is stepped up accordingly, a discharge is indicated for the full-sized siphon of 1,000 c.f.s., which is about what was contemplated in the design. There has been as yet no opportunity for checking the actual capacity of the siphons at Bartlett's Ferry.

The height over the crest necessary to prime was for the model 1¼ inches, and for the full-sized siphon 2¼ inches, or approximately twice. The writer is not aware of any exact analytical explanation of this relation, and would appreciate suggestions along this line.

The actual operation of the siphons is very interesting. They do not come into action with any great amount of surging or shock, but the flow gradually builds up to a maximum over a period of several minutes. Some air is admitted through the air vents, even after the siphons have primed, but it is not possible to tell from observation whether or not the discharge is appreciably reduced by this condition.

On account of the severe pressure and partial vacuum conditions inside the siphons, it was anticipated that the interior surfaces might be worn by the water, especially at the roof downstream from the water seal, where the water tends to leave the surface of the concrete and cavitation might be expected. Castings and steel wearing plates were accordingly embedded in the concrete at critical points, and the entire interior of each siphon was given several coats of tar. When inspected several months after the spillway went into operation, most of this tar coating was still in place.

When the plant is shut down and the reservoir level rises, all surplus water up to the capacity of the siphons is automatically wasted without the manipulation of gates. After the crest gates have been set to accommodate a particular river stage, small variations in flow are taken care of by the siphons, with a maximum variation in reservoir level of about six inches.

The siphon spillway has in general been very successful as a regulating feature, and should be the means of saving considerable manual gate operation.

MEMOIRS

Frank Clifton Kimball*

Died June 21, 1927

Frank Clifton Kimball, son of Caleb F. and Mary A. (Tilden) Kimball, was born in Stoughton, Mass., on November 23, 1861, and was educated in the public schools. In 1881 he began work with the late Charles F. Parks, C.E., of Waltham. In 1885 Mr. Parks became associated in a partnership with William Wheeler, Mr. Kimball continuing in the employ of the new firm, and after 1889 with Mr. Wheeler, Mr. Parks having retired.

During his connections with Mr. Wheeler and Mr. Parks he had an unusually rich experience, chiefly in connection with water works and other public utilities. This experience included the construction and management of several water works, including the one at Knoxville, Tenn., of which company he was manager from 1899 to 1904. After serving as a Vice-President and General Manager of the Lewiston-Clarkston Company, engaged in an irrigation and power project in Idaho, Mr. Kimball returned to Boston in 1907 and was engaged in several important works with Mr. Wheeler. These included several valuation cases.

On or about March 1, 1912, Mr. Kimball became General Manager of the Commonwealth Water and Light Company of Summit, N. J. After June 1, 1923, the ownership of the company having changed, Mr. Kimball was variously employed, chiefly on valuation and management. These later connections were with the New Jersey Public Utilities Commission, Fuller & McClintock of New York, the Cottage City Water Company, the Exeter Water Works, the North Jersey District Water Supply Commission, the city of Summit, and others.

In 1885 Mr. Kimball married Minnie E. Whittle, who, with one daughter, Florence, survives him.

He was a member of the American Society of Civil Engineers, The Boston Society of Civil Engineers, and the American and the New England Water Works Associations.

Mr. Kimball was a man of unusual ability and fine character. He combined wide practical experience with unusual capacity for analysis. These are evidenced by two papers which he read before the New England Water Works Association, — namely, "Some Six-Inch Meter Tests and How They Were Made" (**17**, 305), and "How the Water Emergency at Worcester, Mass., was Handled in the Summer of 1911" (**26**, 113).

Mr. Kimball won his friends by his fidelity, his fairness of mind, and his generous contributions from his store of experience, especially to the younger members of the profession. A large circle of friends regret his passing and treasure their memories of association with him.

Thomas Howard Barnes†

Died November 15, 1927

Thomas Howard Barnes was born in Waltham, Mass., on December 15, 1860, the son of Phineas H. and Elizabeth Howard (Miles) Barnes. His childhood was spent on a farm, and his early education was obtained in the public schools of Waltham. In 1877 he entered the Massachusetts Institute of Technology with the Class of 1881, but lacked sufficient means to continue after the second year.

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* Memoir prepared by William Wheeler and Robert Spurr Weston.

† Memoir prepared by C. MacCallum, Consulting Engineer, New York City.

His first professional position was as an assistant engineer in the office of the city engineer at Cambridge, Mass. After five years in this position he returned to Waltham as inspector of plumbing for the Board of Health. He was also engaged in private practice as a civil engineer.

In 1887 Mr. Barnes went to Alabama to lay out and plan the town of New Decatur. The following year he went to New Birmingham, Tex., where for four years he was employed in similar work.

After a brief period in the city engineer's office, in Newton, Mass., he again engaged in private practice in Waltham. While there he was appointed engineer of the Medford, Mass., Sewerage Commission, in charge of the design and construction of the sewers of that city. This was followed by his appointment as the first city engineer of Medford. In 1900 he resumed private practice, this time in Boston, Mass., where for the next four years he specialized chiefly in sewerage and water-works design and construction.

In 1904 Mr. Barnes made his first trip to tropical countries, in which field he was later to become an authority. His mission included the study and design of water supply and sewage disposal systems in the cities of San José, and Puerto Limon, Costa Rica. He then went to Bocas del Toro, Panama, to undertake the filling and sanitation of that port. The site of the town was a mangrove swamp, which made it necessary for all buildings to be erected on piles; elevated plank walks served as streets, and the ebb and flow of the tides was the sole and dubious means of sewage disposal. A sea wall was built around this town, sewer pipes were laid, and sand, which had been dredged from the harbor bottom, was pumped in. Thus the transformation from an unlivable jungle site to a healthy town was complete. Mr. Barnes later served as engineer on other projects of a similar nature.

While engaged in the work at Bocas del Toro, Mr. Barnes was retained by the United Fruit Company to design and construct a wharf at Almirante, Panama, which town was the outlet for the banana trade from the Company's entire Changuinola Division. This wharf, it is believed, was the first to be built of reinforced concrete, and, until its completion and a thorough demonstration of its reliability, was a source of concern to many engineers and practical construction men. Time demonstrated the soundness of the design, and today the wharf stands as an example of resistance to deterioration under unfavorable tropical conditions. Other wharves of a similar type were designed and built in various ports in Central America, many of them by Mr. Barnes, until he came to be recognized as an authority on tropical wharf construction.

From 1908 to 1913 Mr. Barnes served both the United Fruit Company and the International Railways of Central America. His work included the design and construction of wharves, hospitals, warehouses, office buildings, water works, sewerage plants, and other projects in Guatemala, Salvador, Honduras, Panama, Colombia, and Jamaica. From 1913 to 1918 he acted as consulting engineer for these two companies, with headquarters in New York, with frequent trips to Central America and the West Indies.

In 1918 he re-entered private practice as a consultant on tropical engineering. During the ensuing nine years he served such companies as the International Railways of Central America, the Demerara Boxite Company, the Cuyamel Fruit Company, and the International Products Corporation, as well as several of the large oil companies and various Latin-American municipalities and governments. His more important work included a $3,000,000 beef-packing plant and dock facilities at Covenas, Colombia;

hospital designs for Santo Domingo, Dominican Republic, Maracaibo, Venezuela, Cartagena, Colombia, and Puerto Cortes, Honduras; railroad shops in Salvador and Guatemala; wharf construction at Puerto Barrios, Guatemala; work for the American Legation at San Salvador; and a harbor and dock improvement project of great magnitude in Callao Harbor, Peru, on which he was engaged at the time of his death.

During his twenty-three years' practice in tropical engineering, Mr. Barnes visited virtually every country, and every important town in Central America and the West Indies. His grasp of the human and economic, as well as the strictly technical, aspects of tropical problems gained for him the respect of the many important companies which he served. Time and again it was necessary, first, to plan and provide sanitary measures, living quarters, water and food supply, and to import labor and the most elementary building material before actual work on the project in hand could be started.

His consideration for the physical and mental well-being of his employees, high and low, and his unswerving fairness and loyalty to them, won for him not only respect but unalloyed affection. His knowledge of the Spanish language and the Spanish temperament, combined with a singular mixture of uncompromising uprightness and firmness of purpose, and his realization of the devious circumlocution necessary in negotiating with Latin-Americans, commanded for him widespread respect and prestige, and a measure of personal affection seldom accorded a "gringo."

The following tribute comes from his class, 1881:

Howard was one among us who seemed to have discovered the fountain of perpetual youth. His sturdy figure and pleasant, smiling countenance underwent little apparent change as the years rolled by. Youthful enthusiasm and the joyful zest for living were undiminished, and whenever he returned from the south countries — after long or short absence — he slipped into his accustomed seat by the fireside of our friendship quite naturally and without undue commotion. And so — for all his friends, men who knew him for a generation or for some shorter period — Howard has gone back to his Far Country, but the seat by the fireside shall be his always.

On April 30, 1890, Mr. Barnes was married to Martha Middleton Simmons of Rusk, Tex., who, with a son, Harold Simmons, of Upper Montclair, N. J., and a daughter, Eleanor, of Yonkers, N. Y., survives him.

Mr. Barnes was a member of the Boston Society of Civil Engineers; the New England Water Works Association; the American Water Works Association; the American Public Health Association; and the American Association of Port Authorities. His clubs were the following: The Technology Club of New York; the Park Hill (Yonkers) Community Club; the Whitehall Club; and the Surf Club of Cartagena, Colombia. He was a trustee of the Church of the Divine Paternity (Universalist), New York, N. Y., and he was also a Free Mason. On numerous occasions he contributed technical articles to the various engineering societies, which were of genuine merit.

Mr. Barnes was elected a member of the Boston Society of Civil Engineers on December 21, 1892.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

JANUARY 25, 1928. — A regular meeting of the Boston Society of Civil Engineers was held today in Chipman Hall, Tremont Temple, and was called to order by Vice-President Frank E. Winsor, at 7.15 P.M. There were 140 members and guests present.

The minutes of the previous meeting (November 16, 1927) were approved as published in the December JOURNAL.

The Secretary reported that the Board of Government had elected the following to membership:

December 21, 1927. *Member:* Oliver B. Brown,* E. W. Danforth, Herman G. Dresser, Walton H. Sears, Charles E. Tirrell. *Associate:* Edward Grossman.

January 25, 1928. *Member:* Athole B. Edwards.

The Vice-President reported the death of the following members:

Thomas Howard Barnes, November 15, 1927, a member since December 21, 1892; George Ansel Carpenter, December 15, 1927, a member since May 16, 1894; and Charles Edward Chandler, January 6, 1928, a member since April 20, 1904.

He stated that committees would be appointed to prepare memoirs.

The Vice-President called attention to the campaign for new members being made by the Membership Committee, and urged the co-operation of all the members of the Society.

The Secretary announced that a Joint Meeting with the Northeastern Section, American Society of Civil Engineers, and with the Student Civil Engineering Societies of Massachusetts Institute of Technology, Harvard, Tufts and Northeastern University would be held on February 15, 1928, at which John H. Gregory of Baltimore would give an illustrated talk on "The O'Shaughnessy Dam and Reservoir."

The Vice-President then introduced John J. Harty, Consulting Engineer, who gave an illustrated talk on "Concrete and other Building Materials in Exposed Locations." Messrs. A. L. Shaw, H. S. Cleverdon, E. A. Dockstader (for L. J. Towne), B. A. Rich, B. R. Switzer (for A. B. MacMillan), and Col. S. E. Thompson presented papers on this topic. Following this a general discussion took place in which E. H. Cameron, I. B. Crosby, E. A. Varney and W. C. Voss took part.

Meeting adjourned at 9.45 P.M.

J. B. BABCOCK, *Secretary.*

Highway Section

DECEMBER 28, 1927. — A meeting of the Highway Section of the Boston Society of Civil Engineers was held December 28, 1927, in the Affiliation Rooms.

Mr. Charles F. Knowlton, President, Simpson Brothers Corporation, was the speaker of the evening, and gave a very interesting talk on the subject of "Resurfacing Worn and Defective Pavements, — Macadam, Concrete, Brick, Granite Block."

The talk was illustrated by slides and was followed by a lively discussion.

About 60 members and guests were present.

H. F. MACWILLIAMS, *Clerk.*

Sanitary Section

JANUARY 4, 1928. — A meeting of the Sanitary Section was held in the Library of the Affiliated Technical Societies on Wednesday, January 4, 1928. The dinner at Marston's, which preceded the meeting, was attended by 29 members.

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* Transferred from grade of Junior.

The Section meeting was called to order at 7.20 by the Chairman, who introduced Harold K. Barrows, Professor of Hydraulic Engineering at the Massachusetts Institute of Technology. Professor Barrows spoke upon the subject of "Floods in New England and Flood Prevention," dealing particularly with the recent flood in Vermont. Professor Barrows described the damage caused by the flood at various places in Vermont and the cause of such floods, together with the effect of providing storage reservoirs to regulate and control the run-off, thereby preventing the occurrence of floods in the future. The talk was illustrated with fifty lantern slides.

In the discussion which followed, Mr. Kennison presented additional data and facts collected by the United States Geological Survey in regard to the recent Vermont flood. Mr. Kimball discussed some of the factors in relation to the work of the Miami Conservancy District. Mr. Sherman discussed studies for flood prevention at San Antonio, Texas, and Mr. Cutter pointed out some of his own observations at Randolph, New Hampshire, during the same storm which caused the flood damage in Vermont.

There were 90 present at the meeting.

The meeting adjourned at 9.10 P.M.

R. W. Horne, *Clerk*.

APPLICATIONS FOR MEMBERSHIP

[February 20, 1928]

The By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

Barstow, Harry Loren, Watertown, Mass. (Age 25, b. Methuen, Mass.) Graduate of high school in Paterson, N. J., in 1921, after which he worked in a chemical manufacturing plant until November, 1922, and in the textile manufacturing business until February, 1925. He is now a student at Northeastern University, and during co-operative periods has been employed by Mr. Charles Whitney, C.E., Brighton, Mr. Arnold of Medford, Aspinwall & Lincoln, and Schein & Levine. Refers to *W. J. Alcott, Jr.*, *H. B. Alvord*, *C. O. Baird, Jr.*, *J. W. Ingalls*, *W. E. Nightingale*.

Bearse, Nelson, Centerville, Mass. (Age 30, b. Centerville, Mass.) Graduate of Barnstable High School and studied one year at Chauncy Hall School, 1918. In the fall of 1918 enlisted in Naval Reserve Force, serving nine months and graduating at the end of that period from the Harvard Ensign School, April, 1919. After this worked for two years as salesman for the International Times Recording Company. In 1922 took a year's civil engineering course at Northeastern University, working for two and one-half months the following summer for Metcalf & Eddy at Hopedale. In 1923 started in engineering business for himself on Cape Cod, with an office at Centerville, where he is at present located. Refers to *H. P. Eddy, Jr.*, *C. S. Ell*, *C. B. Humphrey*, *J. W. Ingalls*.

Burton, Harold L., Boston, Mass. (Age 20, b. Boston, Mass.) Is a student at Northeastern University, and during co-operative periods has been employed by the Commonwealth of Massachusetts as rodman; as chainman by New York, New Haven & Hartford Railroad; and is now transitman for Hartley L. White. Refers to *H. B. Alvord, C. O. Baird, Jr., C. S. Ell, J. W. Ingalls, W. E. Nightingale.*

Collis, Leslie N., Salisbury, Mass. (Age 19, b. Amesbury, Mass.) Is a student at Northeastern University, and during co-operative periods has been employed by the Commonwealth of Massachusetts as a rodman. Refers to *W. J. Alcott, Jr., H. B. Alvord, C. O. Baird, Jr., J. W. Ingalls, W. E. Nightingale.*

Delany, Edwin Francis, Brookline, Mass. (Age 29, b. Cambridge, Mass.) Graduate of Massachusetts Institute of Technology, with degree of C. E., in 1921. From June, 1921, to October, appraisal survey, New York Edison Co.; October, 1921, to February, 1922, rate investigation, Boston Edison; February, 1922, to November, with U. S. Coast and Geodetic Survey; December, 1922, to April, 1923, with Boston City Planning Board; April, 1923, to August, Division Engineer's office, Chicago Division, Pennsylvania R.R.; August, 1923, to November, assistant estimator, Bierd, Lydon & Grand Pré, contractors, Chicago; December, 1923, to date, engineer for City Planning Board, Boston. Refers to *J. B. Babcock, C. R. Berry, F. H. Fay, C. R. Gow, E. H. Rogers.*

Flye, Allen Melville, Methuen, Mass. (Age 20, b. Methuen, Mass.) Is a student at Northeastern University. Refers to *W. J. Alcott, Jr., H. B. Alvord, C. O. Baird, Jr., J. W. Ingalls, W. E. Nightingale.*

Goodwin, Ernest Roland, Lynn, Mass. (Age 20, b. Lynn, Mass.) Entered Northeastern University in the fall of 1926, and during the co-operative periods is employed by the city of Waltham as instrumentman. Refers to *W. J. Alcott, Jr., H. B. Alvord, C. O. Baird, Jr., G. A. Haskins, J. W. Ingalls.*

Hanson, Allan Vincent, Everett, Mass. (Age 20, b. Everett, Mass.) Is a student at Northeastern University, and during co-operative periods is with Aspinwall & Lincoln. Refers to *W. J. Alcott, Jr., H. B. Alvord, C. O. Baird, Jr., J. W. Ingalls, W. E. Nightingale.*

Hatch, Theodore Frederick, Cambridge, Mass. (Age 26, b. Islesboro, Me.) Graduate of University of Maine with degree B.S. in civil engineering; also a graduate of Harvard University, department of sanitary engineering, with degree of M.S. in municipal and sanitary engineering. During summer of 1924 was with Rockland & Rockport Water District on survey and mapping of water supply system; July, 1925, to September, 1926, assistant sanitary engineer, with the State Department of Public Health, Nashville, Tenn.; September, 1926, to date, instructor in sanitary engineering at Harvard Engineering School. Refers to *H. P. Burden, G. M. Fair, F. L. Flood, G. E. Griffin.*

Mariner, William Seward, Cambridge, Mass. (Age 21, b. New York, N. Y.) Entered Harvard Engineering School in 1923. During that summer worked as rodman for Mr. H. S. Lewis, Beaver Falls, N. Y.; during the summer of 1925 at the Engineering Camp; from June to January of 1926 and 1927 was instrument man for New England Public Service Company. At present is a senior at Harvard Engineering School. Refers to *G. M. Fair, H. J. Hughes, L. J. Johnson, G. F. Swain, H. M. Turner.*

Marion, John, Chelsea, Mass. (Age 21, b. Chelsea, Mass.) Is a student at Northeastern University, and during co-operative periods has been employed by the Boston & Maine Railroad, and several private engineers. At present is with the Boston & Albany Railroad. Refers to *W. J. Alcott, Jr., H. B. Alvord, C. O. Baird, Jr., J. W. Ingalls, W. E. Nightingale.*

McManamin, Edward F., Wakefield, Mass. (Age 21, b. Wakefield, Mass.) Is a student at Northeastern University, and during co-operative periods has been employed by L. J. Leary of Lynn; John F. Vaughan, Engineers, as transitman by Norfolk County; Title, Guarantee and Trust Company, New York. Refers to *W. J. Alcott, Jr., H. B. Alvord, C. O. Baird, Jr., J. W. Ingalls, W. E. Nightingale.*

Montague, Everett N., West Acton, Mass. (Age 33, b. Concord, Mass.) Graduate of Northeastern University with degree of C.E. During co-operative periods was with Boston & Maine Railroad and Massachusetts Land Court, in engineering department; 1917–18, in United States Army; 1918–19, in survey camp, Lee, Va.; 1919–21, with Stone & Webster, Inc.; 1921–23, with Metropolitan Life Insurance Company; 1923–25, n private practice, civil engineering; 1926–27, engineering department, Massachusetts Land Court; 1927–28, in private practice. Refers to *C. S. Ell, F. L. Flood, C. B. Humphrey.*

Morse, G. Albert A., West Newton, Mass. (Age 30, b. Weston, Mass.) Graduate of Massachusetts Institute of Technology in 1915. From 1915–16 was in the engineering department, city of Newton, as rodman from April, 1917, to October, 1918; instrumentman from October, 1918, to January, 1924; and chief of party from January, 1924, to January, 1928. Refers to *I. W. Hastings, W. P. Morse, A. Q. Robinson, G. E. Stuart.*

Neil, Dexter S., Newark, N. J. (Age 22, b. Lowell, Mass.) Is a student at Northeastern University, and during co-operative periods is employed by Turner Construction Company, where he has been timekeeper, material man, job accountant on building construction, and at present is acting as timekeeper on Bell Telephone job in Newark, N. J. Refers to *H. B. Alvord, G. A. Haskins, Channing Howard, J. W. Ingalls, W. D. Lavers.*

Nelson, Arvo Alfred, Quincy, Mass. (Age 19, b. Quincy, Mass.) Is a student at Northeastern University, and during co-operative periods is employed by E. W. Branch, in Quincy. Refers to *E. W. Branch, J. W. Ingalls, G. H. Newcomb, W. E. Nightingale.*

Nelson, Arthur Lindsay, Waban, Mass. (Age 35, b. Charlottetown, Canada.) Graduate of Massachusetts Institute of Technology in 1915, and later studied at Boston University in the School of Business Administration. In vacations from 1910 to 1915 worked for Hugh Nawn Contracting Company; 1915–17 was electrical engineer with C. H. Tenney & Co.; 1917–19 was Lieutenant in United States Navy; 1919 to date, with Jackson & Moreland as manager of construction department. Refers to *E. H. Cameron, W. D. Henderson, D. C. Jackson, E. L. Moreland, H. B. Perry.*

Sampson, Thomas James, Portland, Me. (Age 43, b. Brooklyn, N. Y.) From January, 1903, to June, 1906, was in sea service and obtained chief engineer's license; June, 1906, to December, 1907, was stakesetter, engineer and draftsman with Standard Dredging Company in harbor improvements, Baltimore Harbor and Chesapeake Bay; December, 1907, to February, 1911, with Standard Dredging Company, in harbor improvements at San Juan, P. R., and during these three years studied civil engineering by correspondence and under private tuition; February, 1911, to December, 1911, with United States Engineer Department as inspector, harbor improvements, San Juan, P. R.; January, 1912, to December, 1915, in private practice as contractor and builder; January, 1916, to November, 1917, inspector, building Navassa Island Light Station, Caribbean Sea; January, 1918, to date, with United States Lighthouse Service as assistant superintendent, assistant lighthouse engineer, and associate lighthouse engineer. Refers to *E. P. Adams, R. F. Bennett, Royal Luther.*

Smith, Gilbert H., Dorchester, Mass. (Age 58, b. Boston, Mass.) Educated in Boston Public Schools. Special student at Massachusetts Institute of Technology, 1887. Architect in Boston for fifteen years, building inspector, Boston building department for seventeen years, and is now in this department. Refers to *B. S. Brown, J. E. Cahill, Hyman Felderman, L. K. Rourke, Carl Stuetzel, Jr.*

Swanson, George S., Dorchester, Mass. (Age 34, b. Boston, Mass.) Graduate of Tufts College with degree B.S. in mechanical engineering. From 1911–14, surveying for Boston & Albany Railroad; in World War, 1917–19; 1921–22, drafting, with Jackson & Moreland; 1922–24, teaching at Tufts College; 1925 to date, with Jackson & Moreland, as engineer. Refers to *E. H. Cameron, W. D. Henderson, E. L. Moreland, H. B. Perry, F. N. Weaver.*

For Transfer from Grade of Junior

McCarthy, Edward R., Natick, Mass. (Age 25, b. Natick, Mass.) Graduate of Tufts College, working during summers as transitman and assistant engineer for Massachusetts Department of Public Works, Division of Highways; 1925–28, with United States Coast and Geodetic Survey as junior hydrographic and geodetic engineer. Refers to *Robinson Abbott, H. P. Burden, L. M. Hersum, E. H. Wright.*

NEW MEMBERS

Members

Otis D. Allen, 22 Broadway, Watertown, Mass.
Morris G. Blumberg, 164 Harvard Street, Brookline, Mass.
Charles L. Coburn, 347 Massachusetts Avenue, Lexington, Mass.
Wilbur S. Colby, 15 Lynde Street, Salem, Mass.
Athole B. Edwards, 4 West Cedar Street, Boston, Mass.
Henry I. Fitz, 36 Irving Street, Boston, Mass.
Albert Genaske, 266 Commonwealth Avenue, Chestnut Hill, Mass.
Stanley A. Higgins, 35A Parker Street, Lexington, Mass.
Donald E. Moore, 29 Maple Avenue, Cambridge, Mass.
G. Howard Perkins, care of Warren Brothers, Inc., P. O. Box 1869, Boston, Mass.
Walter J. Reed, 31 Kahler Avenue, Milton, Mass.
Samuel W. Sweeney, 1205 Brook Road, East Milton, Mass.
Walter C. Voss, Old Town Road, Wellesley, Mass.
Francis B. Wilkins, 1 Chapman Terrace, Beverly, Mass.

Juniors

Theodore F. W. Dunn, Charles River Village, Mass.
Frank Heaney, 123 River Street, Braintree, Mass.
Irving J. Rosenfield, 57 Pine Street, Milford, Mass.
Arthur I. Wistreich, 211 Columbia Road, Dorchester, Mass.

DEATH

Sturgis Hooper Thorndike, February 16, 1928.

BOOK REVIEW

*"Structural Engineering — Stresses, Graphical Statics and Masonry," by George F. Swain, Professor of Civil Engineering at Harvard University and Consulting Engineer. First Edition, 1927. McGraw-Hill Book Company, Inc. 525 pages.**

Volume III of Structural Engineering, entitled "Stresses, Graphical Statics and Masonry," by Prof. George Fillmore Swain, is now offered by the McGraw-Hill Book Company, and takes its place as the third of the five-volume series planned by the well-known Harvard professor.

As can be said of the preceding volumes, "Fundamental Properties of Materials" and "Strength of Materials," it is as complete as it is reasonably possible to expect of any book of its kind, the chapters on loads, impact, earth pressure and arches being particularly complete.

Professor Swain begins his volume with a discussion of structural loads, his early chapters being a summary of material weights, building code live loads, railway and highway wheel loads and wind pressure, all receiving a more thorough treatment than is usual in a textbook.

The section on stresses includes the usual and necessary treatment of standard types of trusses, skew bridges and some historical data. Considerable use is made of influence lines, and a chapter is offered on the economics of simple trusses.

The chapters on graphic statics are somewhat advanced in character and very complete. Many diagrams are included which are well conceived and arranged, but are not so well executed by the publishers.

A chapter on dimensioning contains a summary of many specifications requirements, factors of safety and effects of repetition and reversal of stress. Impact is treated in an analytical manner, and methods of allowing for impact effect by specification and formula are contrasted.

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* Reviewed by Robinson Abbott, Assistant Professor of Civil Engineering at Tufts College.

Earth pressure includes surcharge, granular and saturated materials, cohesion, Mohr's theory, Rankine's theory and its limitations, and a discussion of the uncertainty of theoretical calculations of earth pressure. A summary of much experimental data and the theory of pressures of granular materials in bins and elevators is included in the seventy-five pages devoted to this general subject.

The chapters on masonry include masonry classification, bonding, joints, stone cutting and brief specifications for many common types of masonry structures. Gravity and reinforced retaining walls are discussed. Piers and abutments, both regular and skew, and concrete crib retaining walls are included.

Arch analysis and a study of the stone arch are considered in a separate section, and some space is devoted to a discussion of the stresses in an arch ring concerning which Professor Swain takes some issue with Prof. C. C. Williams and Prof. Ira O. Baker on the matter of lines of resistance. Professor Swain's general method is outlined at length, and there is discussion of the skew and groined arch and arch centering for large and small construction. Elastic theory of arches is not covered, it being reserved for Volume 5 of the series.

The last chapter is that on dams, — gravity, masonry, arch and multiple arch, hollow, earth, log and movable types, each receiving a brief consideration.

Scattered throughout the book are to be found contrasting statements of commonly used methods of analysis and ideas of theoretical origin which apply to the subject therein discussed, after which Professor Swain usually sets down his own personal opinion if the subject is one which appreciably involves controversy. The opinion of this writer and student of engineering, and the results of his fruitful experience, may well be thoughtfully considered by all.

This review would not be complete if the two books that are to follow this volume were not mentioned. They are to be entitled Volume IV, Design, and Volume V, Indeterminate Structures, and after reading some of the manuscript of Volume IV your reviewer feels that no one, except, possibly, Prof. Mansfield Merriman, has yet made so thorough, so complete, and incidentally so readable, a contribution to engineering literature as has Professor Swain.

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FOUNDED 1848

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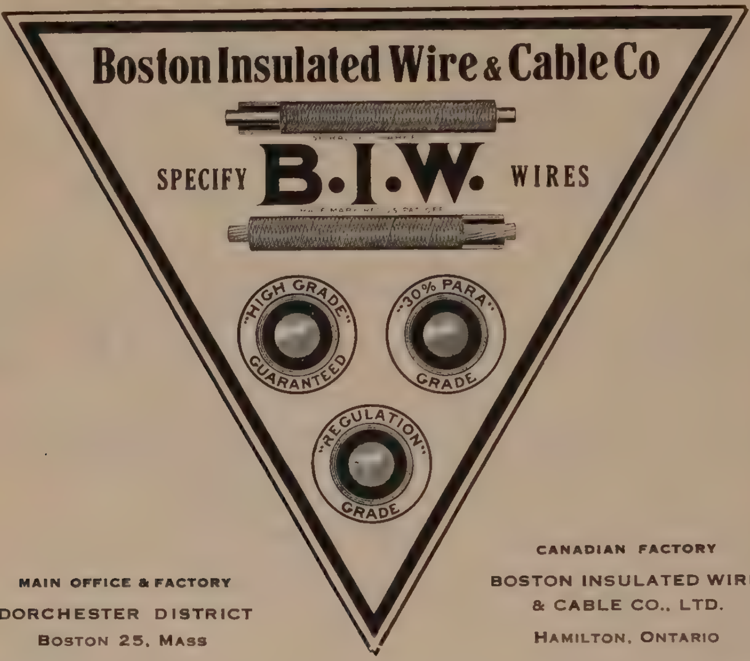

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